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THE HERRING.*

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IT is now nineteen years since my attention was first specially directed to the natural history of the herring, and to the many important economical and legal questions connected with the herring-fisheries. As a member of two successive Royal Commissions, it fell to my lot to take part in inquiries held at every important fishing-station in the United Kingdom between the years 1862 and 1865, and to hear all that practical fishermen had to tell about the matter; while I had free access to the official records of the Fishery Boards. Nor did I neglect such opportunities as presented themselves of studying the fish itself, and of determining the scientific value of the terms by which, in the language of fishermen, the various conditions of the herring are distinguished.

Diligent sifting of the body of evidence thus collected and passed under review led to the satisfactory clearing away, in my own mind, of some of the obscurities which, at that time, surrounded the natural history of the fish. But many problems remained, the solution of which was not practicable by investigations which, after all, were only incidents in the course of a large inquiry, embracing a vast number of topics besides herrings and herring-fisheries; and it is only within the last few years that the labors of the German West Baltic Fishery Commission have made such large additions to the state of our knowledge in 1865 that the history of the herring is brought within measurable distance of completeness.

Considering the vast importance of the herring-fisheries of the eastern counties, it occurred to me, when the President of the National

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Fishery Exhibition did me the honor to ask me to address you, that nothing could be more likely to interest my audience than a summary statement of what is now really known about a fish which, from a fisherman's point of view, is probably the chief of fishes.

I am aware that I may lay myself open to the application of the proverb about carrying coals to Newcastle if I commence my observations with a description of the most important distinctive characters of a fish which is so familiar to the majority of my hearers. And perhaps it is as well that I should at once express my belief that most of you are as little likely to mistake a herring for anything else as I am. Nay, I will go further. I have reason to believe that any herring-merchant, in a large way of business, who may be here, knows these fish so much better than I do that he is able to discriminate a Yarmouth herring from a Scotch herring, and both from a Norway herring; a feat which I could not undertake to perform. But then it is possible that I may know some things that he does not. He is very unlike other fishermen and fish-merchants with whom I have met, if he has any but the vaguest notions of the way of life of the fish; or if he has heard anything about those singularities of its organization which perplex biologists; or if he can say exactly how and why he knows that a herring is not a sprat, a shad, or a pilchard. And all kinds of real knowledge and insight into the facts of nature do so bear upon one another and turn out in strange ways practically helpful that I propose to pour out my scientific budget, in the hope that something more may come of it than the gratification of intelligent curiosity.

If any one wants to exemplify the meaning of the word "fish," he can not choose a better animal than a herring. The body, tapering to each end, is covered with thin, flexible scales, which are very easily rubbed off. The taper head, with its underhung jaw, is smooth and scaleless on the top; the large eye is partly covered by two folds of transparent skin, like eyelids—only immovable and with the slit between them vertical instead of horizontal; the cleft behind the gill-cover is very wide, and, when the cover is raised, the large red gills which lie beneath it are freely exposed. The rounded back bears the single moderately long dorsal fin about its middle. The tail-fin is deeply cleft, and on careful inspection small scales are seen to be continued from the body, on to both its upper and its lower lobes, but there is no longitudinal scaly fold on either of these. The belly comes to an edge, covered by a series of sharply-keeled bony shields between the throat and the vent; and behind the last is the anal fin, which is of the same length as the dorsal fin. There is a pair of fore-limbs, or pectoral fins, just behind the head; and a pair of hind-limbs, or ventral fins, are situated beneath the dorsal fin, a little behind a vertical line drawn from its front edge, and a long way in front of the vent. These fins have bony supports or rays, all of which are soft and jointed.

Like most fishes, the herring is propelled chiefly by the sculling action of the tail-fin, the rest serving chiefly to preserve the balance of the body, and to keep it from turning over, as it would do if left to itself, the back being the heaviest part of the fish.

The mouth of the herring is not very large, the gape extending back only to beneath the middle of the eye, and the teeth on the upper and lower jaws are so small as to be hardly visible. Moreover, when a live herring opens its mouth, or when the lower jaw of a dead herring is depressed artificially, the upper jaw, instead of remaining fixed and stationary, travels downward and forward in such a manner as to guard the sides of the gape. This movement is the result of a curious mechanical arrangement by which the lower jaw pulls upon the upper, and I suspect that it is useful in guarding the sides of the gape when the fish gulps the small living prey upon which it feeds.

The only conspicuous teeth, and they are very small, are disposed in an elongated patch upon the tongue, and in another such patch, opposite to these, on the fore part of the roof of the mouth. The latter are attached to a bone called the vomer, and are hence termed vomerine teeth. But, if the mouth of a herring is opened widely, there will be seen, on each side, a great number of fine, long, bristle-like processes, the pointed ends of which project forward. These are what are termed the gill-rakers, inasmuch as they are fixed, like the teeth of a rake, to the inner sides of those arches of bone on the outer sides of which the gills are fixed. The sides of the throat of a herring, in fact, are, as it were, cut by four deep and wide clefts, which are separated by these gill arches, and the water which the fish constantly gulps in by the mouth flows through these clefts, over the gills and out beneath the gill-covers, aërating the blood, and thus effecting respiration, as it goes. But, since it would be highly inconvenient, and indeed injurious, were the food to slip out in the same way, these gill-rakers play the part of a fine sieve, which lets the water strain off, while it keeps the food in. The gill-rakers of the front arches are much longer than those of the hinder arches, and, as each is stiffened by a thread of bone developed in its interior, while, at the same time, its sides are beset with fine sharp teeth, like thorns on a brier, I suspect that they play some part in crushing the life out of the small animals on which the herrings prey.

Between these arches there is, in the middle line, an opening which leads into the gullet. This passes back into a curious conical sac which is commonly termed the stomach, but which has more the character of a crop. Coming off from the under side of the sac and communicating with it by a narrow opening, there is an elogated tubular organ, the walls of which are so thick and muscular that it might almost be compared to a gizzard. It is directed forward, and opens by a narrow prominent aperture into the intestine, which runs straight back to the vent. Attached to the commencement of the intestine

there is a score or more of larger and shorter tubular organs, which are called the pyloric cæca. These open into the intestine, and their apertures may be seen on one side of it, occupying an oval space, in the middle of which they are arranged three in a row.

The chief food of the herring consists of minute crustacea, some of them allied to the shrimps and prawns, but the majority belonging to the same division as the common *Cyclops* of our fresh waters. These tenant many parts of the ocean in such prodigious masses that the water is discolored by them for miles together, and every sweep of a fine net brings up its tens of thousands.

Everybody must have noticed the silvery air-bladder of the herring, which lies immediately under the backbone, and stretches from close to the head to very near the vent, being wide in the middle and tapering off to each end. In its natural state, it is distended with air; and, if it is pricked, the elastic wall shrinks and drives the air out, as as if it were an India-rubber ball. When the connections of this air-bladder are fully explored, it turns out to be one of the most curious parts of the organization of the whole animal.

In the first place, the pointed end of the sac or crop into which the gullet is continued runs back into a very slender duct which turns upward and eventually opens into the middle of the air-bladder. The canal of this duct is so very small and irregularly twisted, that, even if the air-bladder is squeezed, the air does not escape into the sac. But, if air is forced into the sac by means of a blowpipe, the air passes without much difficulty the other way, and the air-bladder becomes fully distended. When the pressure is removed, however, the air-bladder diminishes in size to a certain extent, showing that the air escapes somewhere. And, if the blowing up of the air-bladder is performed while the fish is under water, a fine stream of air-bubbles may be seen to escape close to the vent. Careful anatomical investigation, in fact, shows that the air-bladder does not really end at the point where its silvery coat finishes, but that a delicate tube is continued thence to the left side of the vent, and there ends by an opening of its own.

Now, the air-bladder of all fishes is, to begin with, an outgrowth from the front part of the alimentary canal, and there are a great many fishes in which, as in the herring, it remains throughout life in permanent communication with the gullet. But it is rare to find the duct so far back as in the herring; and, at present, I am not aware that the air-bladder opens externally in any fishes except the herring and a few of its allies.

There is a general agreement among fishermen that herrings sometimes make a squeaking noise when they are first taken out of the water. I have never heard this sound myself, but there is so much concurrent testimony to the fact that I do not doubt it; and it occurs to me that it may be produced, when the herrings are quickly brought

up from some depth, by means of this arrangement. For under these circumstances the air which the air-bladder contains expands to such a degree, on being relieved from the pressure of the water, that deep-sea fishes with a closed air-bladder which are brought to the surface rapidly are sometimes fairly turned inside out by the immense distention, or even bursting, of the air-bladder. If the same thing should happen to the herring, the like misfortune would not befall it, for the air would be forced out of the opening in question, and might readily enough produce the squeak which is reported. The common loach* is said to produce a piping sound by expelling the air which this fish takes into its intestine for respiratory purposes.

At the opposite end of the air-bladder there is an even more curious arrangement. The silvery coat of the air-bladder ends in front just behind the head. But the air-bladder itself does not terminate here. Two very fine canals, each of which is not more than a two-hundredth of an inch in diameter, though it is surrounded by a relatively thick wall of cartilage, pass forward, one on each side, from the air-bladder to the back of the skull. The canals enter the walls of the skull, and then each divides into two branches. Finally, each of these two dilates into a bag which lies in a spheroidal chamber of corresponding size and form; and, in consequence of the air which they contain, these bags may be seen readily enough shining through the side-walls of the skull, the bone of which has a peculiar structure where it surrounds them. Now, these two bags, which constitute the termination of the air-bladder on each side, are in close relation with the organ of hearing. Indeed, a process of that organ projects into the front chamber on each side, and is separated by only a very delicate partition from the terminal sac of the air-bladder. Any vibrations of the air in these sacs, or any change in the pressure of the air in them, must thus tell upon the hearing apparatus.

There is no doubt about the existence of these structures, which, together with the posterior opening of the air-bladder, were most accurately described, more than sixty years ago, by the eminent anatomist Weber; but I am afraid we are not much wiser regarding their meaning than we were when they were first made known. In fishes in general, there can be little doubt that the chief use of the air-bladder is to diminish the specific gravity of the fish, and, by rendering its body of nearly the same weight as so much water, to render the business of swimming easier. In those fishes in which the passage of communication between the air-bladder and the alimentary canal is closed, the air is no doubt secreted into the air-bladder by its vessels, which are often very abundant. In the herring the vessels of the air-bladder are very scanty; and it seems probable that the air is swallowed and forced into the air-bladder just as the loach swallows air and drives it

* See Müller, "Ueber Fische welche Töne von sich geben ("Archiv für Physiologie," 1857, p. 267). The herring is not mentioned in Müller's list of vocal fishes.

into its intestine. And, as I have already suggested, it may be that the narrow posterior canal which leads from the air-bladder to the exterior is a sort of safety-valve allowing the air to escape, when the fish, rapidly ascending or descending, alters the pressure of the water upon the contained air.

This hypothesis may be put forward with some show of probability, but I really find it difficult to suggest anything with respect to the physiological meaning of the connection between the air-bladder and the ear. Nevertheless such an elaborate apparatus must have some physiological importance; and this conclusion is strengthened by the well-known fact that there are a great many fishes in which the air-bladder and the ear become connected in one way or another. In the carp tribe, for example, the front end of the air-bladder is connected by a series of little bones with the organ of hearing, which is, as it were, prolonged backward to meet these bones in the hinder end of the skull. But here the air-bladder, which is very large, may act as a resonator; while in the herring the extreme narrowness of the passages which connect the air-bladder with the ear renders it difficult to suppose that the organ can have any such function.

In addition to the singular connection of the ear with the exterior by the roundabout way of the air-bladder, there are membranous spaces in the walls of the skull by which vibrations can more directly reach the herring's ear. And there is no doubt that the fish is very sensitive to such vibrations. In a dark night, when the water is phosphorescent or, as the fishermen say, there is plenty of "merefire," it is a curious spectacle to watch the effect of sharply tapping the side of the boat as it passes over a shoal. The herrings scatter in all directions, leaving streaks of light behind them, like shooting-stars.

The herring, like other fishes, breathes by means of its gills—the essential part of which consists of the delicate, highly vascular filaments which are set in a double row on the outer faces of each of the gill-arches. The venous blood, which returns from all parts of the body to be collected in the heart, is pumped thence into the gills, and there exchanges its excess of carbonic-acid gas for the gaseous oxygen which is dissolved in sea-water. The freedom of passage of the water and the great size and delicacy of the gills facilitate respiration when the fish is in its native element; but the same peculiarities permitting of the rapid drying and coherence of the gills, and thus bringing on speedy suffocation, render its tenure of life, after removal from the water, as short as that of any fish. It may be observed, in passing, that the wide clefts behind the gill-covers of the herring have some practical importance, as the fish, thrusting its head through the meshes of the drift-net, is caught behind them, and can not extricate itself. In the herring, the upper end of the last gill-cleft is not developed into a sac or pouch, such as we shall find in some of its near neighbors.

The only other organs of the herring, which need be mentioned at present, are the milt and roe, found in the male and female herring respectively.

These are elongated organs attached beneath the air-bladder, which lie, one on each side of the abdominal cavity, and open behind the vent by an aperture common to the two. The spermatic fluid of the male is developed in the milt and the eggs of the female in the roe. These eggs, when fully formed, measure from one sixteenth to one twenty-fifth of an inch in diameter; and as, in the ripe female, the two roes or ovaries stretch from one end of the abdominal cavity to the other, occupying all the space left by the other organs, and distending the cavity, the number of eggs which they contain must be very great. Probably 10,000 is an under-estimate of the number of ripe eggs shed in spawning by a moderate-sized female herring. But I think it is safer than the 30,000 of some estimates, which appear to me to be made in forgetfulness of the very simple anatomical considerations that the roe consists of an extensive vascular framework as well as of eggs; and, moreover, that a vast number of the eggs which it contains remain immature, and are not shed at the time of spawning.

In this brief account of the structure of the herring I have touched only on those points which are peculiarly interesting, or which bear upon what I shall have to say by-and-by. An exhaustive study of the fish from this point of view alone would require a whole course of lectures to itself.

The herring is a member of a very large group of fishes spread over all parts of the world, and termed that of the *Clupeidæ*, after *Clupea*, the generic name of the herring itself. Our herring, the *Clupea harengus*, inhabits the White Sea, and perhaps some parts of the Arctic Ocean, the temperate and colder parts of the Atlantic, the North Sea, and the Baltic, and there is a very similar, if not identical, species in the North Pacific. But it is not known to occur in the seas of Southern Europe, nor in any part of the intertropical ocean, nor in the southern hemisphere.

There are four British fishes which so closely resemble herrings, externally and internally, that, though practical men may not be in any danger of confounding them, scientific zoölogists have not always succeeded in defining their differences. These are the Sprat, the Allice and Twaite Shads, and the Pilchard.

The sprat comes nearest; indeed, young herrings and sprats have often been confounded together, and doubts have been thrown on the specific distinctness of the two. Yet if a sprat and a young herring of the same size are placed side by side, even their external differences leave no doubt of their distinctness. The sprat's lower jaw is shorter; the shields in the middle of the belly have a sharper keel, whence the ventral edge is more like a saw; and the ventral fin lies vertically

under the front edge of the dorsal fin, or even in front of it; while in the herring, though the position of the ventral fin varies a little, it lies more or less behind the front margin of the dorsal fin. The anal fin is of the same length as the dorsal, in the herring, longer than the dorsal in the sprat. But the best marks of distinction are the absence of vomerine teeth in the sprat, and the smaller number of pyloric cæca, which do not exceed nine, their openings being disposed in a single longitudinal series.

Shads and pilchards have a common character by which they are very easily distinguished from both sprat and herring. There is an horizontal fold of scaly skin on each side of the tail above and below the middle line. Moreover, they have no teeth in the inside of the mouth, and their pyloric cæca are very numerous—a hundred or more—their openings being disposed five or six in a row.

The shads have a deep narrow notch in the middle line of the upper jaw, which is absent in the pilchard. The intestine of the shad is short and straight, like that of the herring; while that of the pilchard is long, and folded several times upon itself.

Both of these fishes, again, possess a very curious structure, termed an accessory branchial organ, which is found more highly developed in other fishes of the herring family, and attains its greatest development in a fresh-water fish, the *Heterotis*, which inhabits the Nile. This organ is very rudimentary in the shad (in which it was discovered by Gegenbaur*), but it is much larger in the pilchard, in which, so far as I know, it has not heretofore been noticed. In *Chanos* and several other Clupeoid fishes it becomes coiled upon itself, and in *Heterotis* the coiled organ makes many turns. The organ is commonly supposed to be respiratory in function; but this is very doubtful.

Herrings which have attained maturity, and are distended by the greatly enlarged milt or roe, are ready to shed the contents of these organs, or, as it is said, to spawn. In 1862 we found a great diversity of opinion prevailed as to the time at which this operation takes place, and we took a great deal of trouble to settle the question, with the result which is thus stated in our report:

"We have obtained a very large body of valuable evidence on this subject, derived partly from the examination of fishermen and of others conversant with the herring-fishery; partly from the inspection of the accurate records kept by the fishery officers at different stations, and partly from other sources; and our clear conclusion from all this evidence is, that the herring spawns at two seasons of the year, in the spring and in the autumn. We have hitherto met with no case of full or spawning herrings being found, in any locality, during what may be termed the solstitial months, namely, June and December; and it would appear that such herrings are never (or very rarely) taken in

* "Ueber das Kopfskelet von *Alepocephalus rostratus*" ("Morphologisches Jahrbuch," Bd. iv., Suppl., 1878).

May, or the early part of July, in the latter part of November or the early part of January. But a spring spawning certainly occurs in the latter part of January, in February, in March, and in April; and an autumn spawning in the latter part of July, in August, September, October, and even as late as November. Taking all parts of the British coast together, February and March are the great months for the spring spawning, and August and September for the autumn spawning. It is not at all likely that the same fish spawn twice in the year; on the contrary, the spring and the autumn shoals are probably perfectly distinct; and if the herring, according to the hypothesis advanced above, come to maturity in a year, the shoals of each spawning-season would be the fry of the twelvemonth before. However, no direct evidence can be adduced in favor of this supposition, and it would be extremely difficult to obtain such evidence."*

I believe that these conclusions, confirmatory of those of previous careful observers,† are fully supported by all the evidence which has been collected, and the fact that this species of fish has two spawning-seasons, one in the hottest and one in the coldest months of the year, is very curious.

Another singular circumstance connected with the spawning of the herring is the great variety of the conditions, apart from temperature, to which the fish adapts itself in performing this function. On our own coast, herrings spawn in water of from ten to twenty fathoms, and even at greater depths, and in a sea of full oceanic saltness. Nevertheless, herrings spawn just as freely not only in the narrows of the Baltic, such as the Great Belt, in which the water is not half as salt as it is in the North Sea and in the Atlantic, but even in such long inlets as the Schlei in Schleswig, the water of which is quite drinkable and is inhabited by fresh-water fish. Here the herrings deposit their eggs in two or three feet of water; and they are found, along with the eggs of fresh-water fish, sticking in abundance to such fresh-water plants as *Potamogeton*.

Nature seems thus to offer us a hint as to the way in which a fish like the shad, which is so closely allied to the herring, has acquired the habit of ascending rivers to deposit its eggs in purely fresh water.

If a full female herring is gently squeezed over a vessel of sea-water, the eggs will rapidly pour out and sink to the bottom, to which they immediately adhere with so much tenacity that, in half an hour, the vessel may be inverted without their dropping out. When spawning takes place naturally, the eggs fall to the bottom and attach themselves in a similar fashion, but at this time the assembled fish dart wildly about, and the water becomes cloudy with the shed fluid of the

* "Report of the Royal Commission on the Operation of the Acts relating to Trawling for Herrings on the Coast of Scotland, 1863," p. 28.

† Brandt and Ratzeburgh, for example, in 1833, strongly asserted that the herring has two spawning-seasons.

milt. The eggs thus become fecundated as they fall, and the development of the young within the ova sticking to the bottom commences at once.

The first definite and conclusive evidence as to the manner in which herring-spawn is attached and becomes developed that I know of was obtained by Professor Allman and Dr. MacBain in 1862,* in the Firth of Forth. By dredging in localities in which spent herring were observed on the 1st of March, Professor Allman brought up spawn in abundance at a depth of fourteen to twenty-one fathoms. It was deposited on the surface of the stone, shingle, and gravel, and on old shells and coarse shell-sand, and even on the shells of small living crabs and other crustacea, adhering tenaciously to whatever it had fallen on. No spawn was found in any other part of the Forth; but it continued to be abundant on both the east and the west sides of the Isle of May up to the 13th of March, at which time the incubation of the ovum was found to be completed in a great portion of the spawn, and the embryos had become free. On the 25th scarcely a trace of spawn could be detected, and nearly the whole of the adult fish had left the Forth.

Professor Allman draws attention to the fact that "the deposit of spawn, as evidenced by the appearance of spent herrings, did not take place till about sixty-five days after the appearance of the herring in the Firth," and arrives at the conclusion that "the incubation probably continues during a period of between twenty-five to thirty days," adding, however, that the estimate must, for the present, be regarded as only approximative. It was on this and other evidence that we based our conclusion that the eggs of the herring "are hatched in at most from two to three weeks after deposition."

Within the last few years a clear light has been thrown upon this question by the labors of the West Baltic Fishery Commission, to which I have so often had occasion to refer.† It has been found that artificial fecundation is easily practised, and that the young fish may be kept in aquaria for as long as five months. Thus a great body of accurate information, some of it of a very unexpected character, has been obtained respecting the development of the eggs, and the early condition of the young herring.

It turns out that, as is the case with other fishes, the period of incubation is closely dependent upon warmth. When the water has a temperature of 53° Fahr., the eggs of the herring hatch in from six to

* "Report of the Royal Commission on the Operation of the Acts relating to Trawling for Herrings on the Coast of Scotland, 1863."

† See the four valuable memoirs, Kupffer, "Ueber Laichen und Entwickelung des Herings in der westlichen Ostsee"; idem, "Die Entwickelung des Herings im Ei"; Meyer, "Beobachtungen über den Wachsthum des Herings"; Heincke, "Die Varietäten des Herings," which are contained in the *Jahresbericht der Commission in Kiel für* 1874–'76—1878. Widegren's essay "On the Herring," 1871, translated from the Danish in U. S. Commission Reports, 1873–'75, also contains important information.

eight days; the average being seven days. And this is a very interesting fact when we bear in mind the conclusion to which the inquiries of the Dutch meteorologists, and, more lately, those of the Scottish Meteorological Society, appear to tend, namely, that the shoals prefer water of about 55°. At 50° Fahr., the period of incubation is lengthened to eleven days; at 46° to fifteen days; and at 38° it lasts forty days. As the Forth is usually tolerably cool in the month of March, it is probable that Professor Allman's estimate comes very near the truth for the particular case which he investigated.

The young, when they emerge from the egg, are from one fifth to one third of an inch in length, and so extremely unlike the adult herring that they may properly be termed larvæ. They have enormous eyes, and an exceedingly slender body, with a yelk-bag protruding from its fore-part. The skeleton is in a very rudimentary condition; there are no ventral fins; and, instead of separate dorsal, caudal, and anal fins, there is one continuous fin, extending from the head along the back, round the tail and then forward to the yelk-bag. The intestine is a simple tube, ciliated internally; there is no air-bladder, and no branchiæ are yet developed. The heart is a mere contractile vessel, and the blood is a clear fluid without corpuscles. At first the larvæ do not feed, but merely grow at the expense of the yelk, which gradually diminishes.

Within three or four days after hatching, the length has increased by about half the original dimensions, the yelk has disappeared, the cartilaginous skeleton appears, and the heart becomes divided into its chambers; but the young fish attains nearly double its first length before blood-corpuscles are visible.

By the time the larva is two thirds of an inch long (a length which it attains one month after hatching), the primitive median fin is separated into dorsal, caudal, and anal divisions, but the ventral fins have not appeared. About this period the young animal begins to feed on small crustacea; and it grows so rapidly that, at two months, it is one and a quarter inch long, and, at three months, has attained a length of about two inches.

Nearly up to this stage, the elongated, scaleless little fish retains its larval proportions; but, in the latter part of the third month, the body rapidly deepens, the scales begins to appear, and the larva passes into the "imago" state—that is, assumes the forms and proportions of the adult, though it is not more than two inches long. After this, it goes on growing at the same rate (eleven millimetres, or nearly half an inch) per month, so that, at six months old, it is as large as a moderate-sized sprat.

The well-known "whitebait" of the Thames consists, so far as I have seen, almost exclusively of herrings, under six months old, and as the average size of whitebait increases, from March and April onward, until they become suspiciously like sprats in the late summer, it may

be concluded that they are the progeny of herrings which spawned early in the year, in the neighborhood of the estuary of the Thames, up which these dainty little fish have wandered. Whether it is the general habit of young herring, even of those which are spawned in deep water, to migrate into the shallow parts of the sea, or even into completely fresh waters, when such are accessible, is unknown.

In the "Report on Trawling" (1863) we observe:

"It is extremely difficult to obtain any satisfactory evidence as to the length of time which the herring requires to pass from the embryonic to the adult or *full* condition. Of the fishermen who gave any opinion on this subject, some considered that a herring takes three, and others that it requires seven years to attain the full or spawning condition; others frankly admitted that they knew nothing about the matter; and it was not difficult, by a little cross-examination, to satisfy ourselves that they were all really in this condition, however strongly they might hold by their triennial or septennial theories. Mr. Yarrell and Mr. Mitchell suppose with more reason that herring attain to full size and maturity in about eighteen months.

"It does not appear, however, that there is any good evidence against the supposition that the herring reaches its spawning condition in one year. There is much reason to believe that the eggs are hatched in, at most, from two to three weeks after deposition, and that in six to seven weeks more (that is at most ten weeks from the time of laying the eggs) the young have attained three inches in length. Now, it has been ascertained that a young smolt may leave a river and return to it again in a couple of months increased in bulk eight or ten fold, and, as a herring lives on very much the same food as a smolt, it appears possible that it should increase in the same rapid ratio. Under these circumstances nine months would be ample time for it to enlarge from three to ten or eleven inches in length. It may be fairly argued, however, that it is not very safe to reason analogically from the rate of growth of one species of fish to that of another; and it may be well to leave the question whether the herring attains its maturity in twelve, fifteen, or sixteen months open, in the tolerably firm assurance that the period last named is the maximum."

On comparing these conclusions with the results of the careful observations of the Baltic Commissioners, it appears that we somewhat over-estimated the rate of growth of the young herring, and that the view taken by Yarrell and Mitchell is more nearly correct. For, supposing that the rate of growth after six months continues the same as before, a herring twelve months old will be nearly six inches long, and at eighteen months eight or nine inches. But full herrings may be met with little more than seven inches long, and they are very commonly found not more than nine inches in length.*

* Ljungman ("Preliminary Report on Herrings and Herring Fisheries on the West Coast of Sweden," translated in United States Commission Report, 1873–'75) speaks of

Fishermen distinguish four states of the herring. Fry or sile, when not larger than sprats; maties, when larger than this, with undeveloped roe or milt; full fish, with largely developed roe or milt; and spent or shotten fish, which have recently spawned.

Herring-fry of the size of sprats are distinguished from full fish not merely by their size, but, in addition, by the very slight development of the milt or roe, and by the accumulation of fat in the abdominal cavity. Bands of fat are found in the mesentery alongside the intestine, and filling up the interspaces between the pyloric cæca.

Maties (the name * of which is a corruption of the Dutch word for a maiden) resemble the fry in these particulars; but, if they are well fed, the deposit of fatty and other nutritive matter takes place, not only about the abdominal viscera, but also beneath the skin and in the interstices of the flesh. Indeed, when nourishment is abundant, this infiltration of the flesh with fat may go so far that the fish can not readily be preserved and must be eaten fresh. The singularly delicate Loch Fyne herrings are in this condition early in the season. When the small crustaceans, on which the maties chiefly feed, are extremely abundant the fish gorge themselves with them to such an extent that the conical crop becomes completely distended, and the Scotch fishermen give them the name of "gut-pock" herrings, as much as to say pouch-gutted fish, and an absurd notion is current that these herrings are diseased. However, the "gut-pock" herrings differ from the rest only in having their pouch full instead of empty, as it commonly is.

As the fish passes from the matie to the full condition, the milt and roe begin to grow at the expense of the nutriment thus stored up; and, as these organs become larger and occupy more and more space in the abdominal cavity, the excess of nutritious substance is transferred to them. The fatty deposit about the intestine and pyloric cæca gradually disappears and the flesh becomes poorer. It would appear that by degrees the fish cease to feed at all. At any rate, there is usually no food in the stomach of a herring which approaches maturity. In all these respects there is the closest resemblance between the history of the herring and that of other fishes such as the salmon—the parr corresponding to the herring-fry or sile, the grilse and the "clean fish" of larger size to the maties.

At length spawning takes place, the accumulated nutrition, transformed into eggs or spermatic fluid, is expelled, and the fish is left in

full herrings ready to spawn, only 100–110 millimetres (four to four and a half inches) long, as observed by himself.

* "Halecum intestina, non modo multa gaudere obesitate, sed et totum corpus eo adeo esse impletum ut aliquando, cum discinditur, pinguedo ex cultro defluat, et præsertim eo quidem tempore ubi halecum lactes aut ova crescere primum incipiunt, unde nostrates eos *Maatgens-Haringen* dicere solent."—A. v. Leeuwenhoek, "Arcana Naturæ," Ep. xcvii (1696).

Leeuwenhoek also mentions having heard of "gut-pock" herrings from Scotch fishermen.

that lean and depauperated state which makes a "shotten herring" proverbial. In this condition it answers to the salmon "kelt," and the milt or roe are now shrunk and flaccid and can be blown up with air like empty bags. If the spent fish escapes its myriad enemies, it doubtless begins to feed again and once more passes into the matie state in preparation for the next breeding-season. But the nature of this process of recuperation has yet to be investigated.

When they have reached the matie stage, the herrings, which are at all times gregarious, associate together in conspicuous assemblages, which are called shoals. These are sometimes of prodigious extent—indeed, eight or nine miles in length, two or three in breadth, with an unknown depth, are dimensions which are credibly asserted to be sometimes attained. In these shoals the fish are closely packed, like a flock of sheep straying slowly along a pasture, and it is probably quite safe to assume that there is at least one fish for every cubic foot of water occupied by the shoal. If this be so, every square mile of such a shoal, supposing it to be three fathoms deep, must contain more than 500,000,000 herrings. And when it is considered that many shoals approach the coasts, not only of our own islands, but of Scandinavia and the Baltic, and of Eastern North America, every spring and autumn, the sum total of the herrings which people our seas surpasses imagination.

If you read any old and some new books on the natural history of the herring, you will find a wonderful story about the movements of these shoals: how they start from their home in the polar seas, and march south as a great armada which splits into minor divisions—one destined to spawn on the Scandinavian, and one on our own shores; and how, having achieved this spawning raid, the spent fish make their way as fast as they can back to their Arctic refuge, there to repair their exhausted frames in domestic security. This story was started in the last century, and was unfortunately adopted and disseminated by our countryman Pennant. But there is not the least proof that anything of the kind takes place, and the probabilities are wholly against it. It is, for example, quite irreconcilable with the fact that herring are found in cods' stomachs all the year round. And the circumstance to which I have already adverted, that practiced eyes distinguish local breeds of herrings, though it does not actually negative the migration hypothesis, is very much against it. The supposition that the herring spawn in the north in the early spring, and in the south in the autumn, fitted very well into the notion that the vanguard of the migrating body of herrings occupied the first spawning-ground it reached, and obliged the rest of the horde to pass on. But, as a matter of fact, the northern herrings, like the southern, have two spawning-times; or perhaps it would be more correct to say that the spawning-time extends from autumn to spring, and has two maxima—one in August-September, and one in February-March.

Finally, there is no evidence that herrings are to be met with in the extreme north of their range, at other times, or in greater abundance, than they are to be found elsewhere.

In the matter of its migration, as in other respects, the herring compares best with the salmon. The ordinary habitation of both fishes is no doubt the moderately deep portion of the sea. It is only as the breeding-time draws near that the herrings (not yet advanced beyond the matie state) gather together toward the surface and approach the land in great shoals for the purpose of spawning in relatively or absolutely shallow water. In the case of the herring of the Schlei we have almost the connecting link between the exclusively marine ordinary herring and the river-ascending salmon.

The records of the herring-fisheries are, for the most part, neither very ancient nor (with the exception of those of the Scotch Fishery Board) very accurately kept; and, from the nature of the case, they can only tell us whether the fish in any given year were readily taken or not, and that may have very little to do with the actual strength of the shoals.

However, there is historical evidence that, long before the time of Henry I, Yarmouth was frequented by herring-fishers. This means that, for eight centuries, herrings have been fished on the English coast, and I can not make out, taking one year with another, in recent times, that there has been any serious fluctuation in their numbers. The number captured must have enormously increased in the last two centuries, and yet there is no sign of diminution of the shoals.

In 1864 we had to listen to dolorous prophecies of the coming exhaustion of the Scotch herring-fisheries. The fact that the returns showed no falling off was ascribed to the improvement of the gear and methods of fishing, and to the much greater distances to which the fishermen extend their operations. Yet what has really happened? The returns of subsequent years prove, not only that the average cure of the decade 1869–'78 was considerably greater than that of the previous decade, but that the years 1874 and 1880 are absolutely without parallel in the annals of the Scotch herring-fishery, 1,000,000 barrels having been cured in the first of these years, and 1,500,000 in 1880. In the decade 1859–'68, the average was 670,000 barrels, and the highest 830,000.

In dealing with questions of biology, *a priori* reasoning is somewhat risky, and, if any one tells me "it stands to reason" that such and such things must happen, I generally find reason to doubt the safety of his standing.

It is said that "it stands to reason" that destruction on such a prodigious scale as that effected by herring-fishers must tell on the supply. But again let us look at the facts. It is said that 2,500,000,000, or thereabout, of herrings are every year taken out of the North Sea and the Atlantic. Suppose we assume the number to be 3,000,000,000, so

as to be quite safe. It is a large number undoubtedly, but what does it come to? Not more than that of the herrings which may be contained in one shoal, if it covers half a dozen square miles—and shoals of much larger size are on record. It is safe to say that, scattered through the North Sea and the Atlantic, at one and the same time, there must be scores of shoals, any one of which would go a long way toward supplying the whole of man's consumption of herrings. I do not believe that all the herring-fleets taken together destroy five per cent. of the total number of herrings in the sea in any year, and I see no reason to swerve from the conviction my colleagues and I expressed in our report, that their destructive operations are totally insignificant when compared with those which, as a simple calculation shows, must regularly and normally go on.

Suppose that every mature female herring lays 10,000 eggs, that the fish are not interfered with by man, and that their numbers remain approximately the same year after year, it follows that 9,998 of the progeny of every female must be destroyed before they reach maturity. For, if more than two out of the 10,000 escape destruction, the number of herrings will be proportionately increased. Or, in other words, if the average strength of the shoals which visit a given locality is to remain the same year by year, many thousand times the number contained in those shoals must be annually destroyed. And how this enormous amount of destruction is effected will be obvious to any one who considers the operations of the fin-whales, the porpoises, the gannets, the gulls, the codfish, and the dog-fish, which accompany the shoals and perennially feast upon them; to say nothing of the flat-fish, which prey upon the newly-deposited spawn; or of the mackerel, and the innumerable smaller enemies which devour the fry in all stages of their development. It is no uncommon thing to find five or six—nay, even ten or twelve—herrings in the stomach of a codfish,* and in 1863 we calculated that the whole take of the great Scotch herring-fisheries is less than the number of herrings which would in all probability have been consumed by the codfish captured in the same waters if they had been left in the sea. †

Man, in fact, is but one of a vast coöperative society of herring-catchers, and, the larger the share he takes, the less there is for the rest of the company. If man took none, the other shareholders would have a larger dividend, and would thrive and multiply in proportion, but it would come to pretty much the same thing to the herrings.

* In his valuable "Report on the Salt-Water Fisheries of Norway" (1877), Professor Sars expresses the belief that full-grown codfishes feed chiefly, if not exclusively, on herrings.

† In 1879 rather more than 5,000,000 cod, ling, and hake, were taken by the Scottish fishermen. Allowing each only two herrings a day, these fishes would have consumed more than 3,500,000,000 of herrings in a year. As to the Norwegian fisheries, 20,000,000 codfishes are said to be taken annually by the Loffoden fishermen alone.

As long as the records of history give us information, herrings appear to have abounded on the east coast of the British Islands, and there is nothing to show, so far as I am aware, that, taking an average of years, they were ever either more or less numerous than they are at present. But, in remarkable contrast with this constancy, the shoals of herrings have elsewhere exhibited a change capriciousness—visiting a given locality for many years in great numbers, and then suddenly disappearing. Several well-marked examples of this fickleness are recorded on the west coast of Scotland; but the most remarkable is that furnished by the fisheries of Bohûslan, a province which lies on the southwestern shore of the Scandinavian peninsula. Here a variety known as the "old" or "great" herring, after being so extremely abundant, for about sixty years, as to give rise to a great industry, disappeared in the year 1808, as suddenly as they made their appearance, and have not since been seen in any number.

The desertion of their ordinary grounds by the herring has been attributed to all imaginable causes, from fishing on a Sunday to the offense caused to the fish by the decomposing carcasses of their brethren, dropped upon the bottom out of the nets. The truth is, that absolutely nothing is known on the subject, and that little is likely to be known until careful and long-continued meteorological and zoölogical observations have furnished definite information respecting the changes which take place in the temperature of the sea, and the distribution of the pelagic crustacea which constitute the chief food of the herring-shoals. The institution of systematic observations of this kind is an object of international importance, toward the attainment of which the British, Scandinavian, Dutch, and French Governments might wisely make a combined effort.

A great fuss has been made about trawlers working over the spawning-grounds of the herring. "It stands to reason," we were told, that they must destroy an immense quantity of the spawn. Indeed, this looked so reasonable that we inquired very particularly into a case of the alleged malpractice which was complained of on the east coast of Scotland, near Pittenweem. Off this place there is a famous spawning-ground known as the Traith hole, and we were told that the trawlers worked vigorously over the spot immediately after the herring had deposited their spawn. Of course our first proceeding was to ask the trawlers why they took the trouble of doing what looked like wanton mischief. And their answer was reasonable enough. It was to catch the prodigious abundance of flat-fish which were to be found on the Traith at that time. Well, then, why did the flat-fish congregate there? Simply to feed on herring-eggs, which seem to be a sort of flat-fishes' caviare. The stomachs of the flat-fish brought up by the trawl were, in fact, crammed with masses of herring-eggs.

Thus every flat-fish caught by the trawl was an energetic destroyer

of herring arrested in his career. And the trawling, instead of injuring the herring, captured and removed hosts of their worst enemies. That is how "it stood to reason" when one got to the bottom of the matter.

I do not think that any one who looks carefully into the subject will arrive at any other conclusion than that reached by my colleagues and myself: namely, that the best thing for governments to do in relation to the herring-fisheries is, to let them alone, except in so far as the police of the sea is concerned. With this proviso, let people fish how they like, as they like, and when they like. At present, I must repeat the conviction we expressed so many years ago, that there is not a particle of evidence that anything man does has an appreciable influence on the stock of herrings. It will be time to meddle when any satisfactory evidence that mischief is being done is produced.—*Nature.*

PHYSICAL EDUCATION.

By FELIX L. OSWALD, M. D.

RECREATION.

"Mirth is a remedy."—THOMAS HOBBES.

HAPPINESS is the normal condition of every living creature, for in a state of nature every normal function is connected with a pleasurable sensation. "To enjoy is to obey"; if human life were what it could be and what its Author intended it to be, the path of duty would be a flowery path, the reward of virtue would not be a crown of thorns; man, like all his fellow-creatures, would attain to his highest well-being by simply following the promptings of his instincts. Wild animals have not lost their earthly paradise; he who has observed them in the freedom of their forest homes can not doubt that to them existence is a blessing, and death merely the later or earlier evening of a happy day. Nor would our missionaries find it easy to persuade an able-bodied savage that earth is a vale of tears, till fire-water and fire-arms demonstrate the superiority of revelation over the light of nature. The children of the wilderness need no holidays; to them life itself is a festival and earth a play-ground for manifold games, not the less entertaining for being sometimes spiced with danger or prompted by hunger and thirst.

But in process of time the daily life of a combatant in the harder and harder struggle for existence became so joyless and wearisome that the clamors of an unsatisfied instinct suggested the institution of periodical festivals: pleasure-days intended to offset the tedium of monotonous toil, as gymnastic exercises tend to counteract the influ-

ence of sedentary occupations. The Assyrians and Greeks had tri-monthly holidays, besides annual revels, and great national festivals at longer intervals. In ancient Etruria every new month was ushered in by a day of merrymaking in honor of a tutelary deity; the patricians and plebeians of republican Rome had their field-days; the festivals of the seasons united the pleasure-seekers of all classes, and even the slaves had their Saturnalia weeks when some of their privileges were only limited by their capacity of enjoyment. In the first centuries of the Roman Empire, when the growth of the cities and the scarcity of game began to circumscribe the private pastimes of the poorer classes, the rulers themselves provided the means of public amusements; at the death of Septimus Severus (A. D. 211), the capital alone had six free amphitheatres and twelve or fourteen large public baths, where the poorest were admitted gratis, and none but the poorest could complain about the half-cent entrance-fee to the luxurious *thermæ*. The *circenses*, or public games, were by no means confined to the gladiatorial combats that have exercised the eloquence of our Christian moralists; dramatic entertainments, trials of strength, and the exhibition of outlandish curiosities, seem to have been as popular as the grandest prize-fights, unless the combatants were international champions. And it would be a great mistake to suppose that only the wealthy capital could afford to amuse its citizens at the public expense; from Gaul to Syria every town had a circus or two, every larger village an arena, a free bath, and a public gymnasium. The Colosseum of Vespasian seated eighty thousand spectators, but was rivaled by the amphitheatres of Narbonne, Syracuse, Antioch, Berytus, and Thessalonica.* Children, married women, old men, and many trades-unions had their yearly carnivals, and, during the celebration of the Olympian and Capitoline games and various local festivals, even strangers enjoyed the freedom of the larger towns.

And now?—Professor Wirgmann, in his "Annalen des Russischen Reiches," estimates that since the accession of Nicholas I, the modern Cæsars have expended an average annual sum of seventeen million dollars for the torture of their subjects; how many cents have they ever spent for national pastimes? How many spectators (since the abolition of the "Tyburn-days") have ever been entertained at the expense of the wealthy British Empire? What has our Great Republic done in the matter of *circenses*, except to pass an occasional sabbath law for the suppression of public amusements on the only day in which a large plurality of our workingmen find their only leisure for recreation? The spoils of a Roman consul would dwindle before the rents of our American, German, and French financiers: what have our commercial triumphators ever achieved for the entertainment of their poor fellow-citizens? Cooper Institute lectures, street revivals, and prize distributions at the examination of a sabbath-school for adults?

* Tacitus, "Annalen," xii–xiv.

"At the proposition of such-like pastime," says Ludwig Boerne, "a resurrected citizen of ancient Rome would feel like a filibuster at an invitation to dive for copper coins in a duck-pond, after having chased King Philip's silver fleet on the Spanish Main."

Not poverty makes our daily ways so trite and joyless, for the best recreations are still as free as the air and the sea; nor want of leisure, for we manage to find plenty of time for humdrum ceremonies. The old Egyptians turned their funerals into holidays—we celebrate our holidays like funerals; all the employments of our weekly day of rest are sicklied over with a cast of superstitious fear; and, indeed, no other anachronism of our strangely complex civilization proclaims more loudly the necessity of its divorce from the influence of an anti-natural religion. When that religion reigned supreme, its exponents openly and violently waged war upon all earthly joys; sublunary life, according to their doctrine, was a state of probation for testing a man's power of self-denial; earth was the devil's own, and delight in its pleasures an insult to the jealous ruler of a higher sphere. They believed that God delights in the self-abasement and mortification of his creatures, and hoped to gain his favor by afflicting themselves in every possible way—by voluntary seclusion, fasts, vigils, the wearing of dingy garments, and abstinence from every physical pleasure. Failing to enamor mankind with their doleful heaven, they revenged themselves by depriving them of their earthly joys. In hopes of making the hereafter more attractive, they made life as repulsive as possible; kill-joys and persecutors were the active heroes of those times; ascetics and self-tormentors their passive exemplars. Virtue and joylessness became synonyms; men aspiring to superior merit exchanged the glories of the sunny earth for the misery of a gloomy convent; a "Man of Sorrows" became a type of moral perfection, an instrument of torture, the trade-mark of the new religion. *Kosmos*—i. e., beauty and harmony—was the oldest Grecian term for God's wonderful world; a "vale of tears" the favorite Christian epithet. A symposium of festive heroes was exchanged for a conventicle of whining penitents, Olympus for a charnel-house, the festival of the seasons for the ecclesiastic sabbath: there, a merry multitude, joining in dances and heroic games, inspired by the rapture of emulation, the joy of exuberant health and the beauty of earth till their happiness overflowed in anthems of praise to the bounteous gods; here, a cowed and wretched assemblage, listening with groans to the denunciations of a Nature-hating fanatic. And that hideous superstition founds its claim to our gratitude on its merit of having suppressed a few profligate pastimes—in aiming its death-blows at all earthly joys whatever; as if the crushing of a few poison-plants could atone for the attempt to turn a fertile continent into a sand-waste! The attempt, I say, for I do not believe that either the axe or the cross will for ever mar the beauty of our Mother Earth; the devastated woodlands of the East will ulti-

mately be reclaimed, and here and there the moral desert of asceticism has already begun to bloom with flowers from the revived seeds of Grecian civilization.

Monachism, at least, is fast disappearing; in this age of railroads and steam-engines we have no time for positive self-torture *à la Simon Stylites*. But our commercial Pecksniffs have found it a time- and money-saving plan to stick to the negative part of the anti-pleasure dogma, and hope to atone for the dreary materialism of our daily factory-life by the still drearier asceticism of a Puritan sabbath: six days of misery in the name of Mammon, balanced by one day of sixfold misery in the name of Christ. "Worldly pleasures" are still under the ban of our spiritual purists; daily drudgery and daily self-denial are still considered the proper sphere of a law-abiding citizen, and special afflictions a special sign of divine favor. Life has become a socage-duty; we do not think it necessary to alleviate the distress of our poor till it reaches a degree that threatens to end it. We have countless benevolent institutions for the prevention of outright death, not one benevolent enough to make life worth living. Infanticide is now far more rigorously punished than in old times; we enforce every child's right to live and become a humble, tithe-paying Christian, but as for its claim to live happy we refer it to the sweet by-and-by. We shudder at the barbarity of the Cæsars, who permitted the combat of men with wild beasts, to cater to the amusement of the Roman populace; but we contemplate with great equanimity the misery of millions of our fellow-citizens, wearing away their lives in workshops and factories; millions of children of our own nation and country, who have no recreation but sleep, no hope but oblivion, to whom the morning sun brings the summons of a taskmaster and the summer season nothing but lengthened hours of weary toil; nay, we make it the boast of our pious civilization to deprive them of their sole day of leisure, to interdict their harmless sports, lest the noise, or even the rumor of their merriment, might disturb the solemnity of an assemblage of whining hypocrites. Hence the recklessness, the Nihilism, and the weary pessimism of our times, the melancholy that everywhere underlies the glittering varnish of our social life. Hence also that vague yearning after a happy hereafter, which the murderers of the happy past have made the principal source of their revenues.

With few exceptions the children of Christendom are stricken with a disease which mirth alone can cure. In North America and North Britain, especially, it is pitiful to witness the slow withering of so many light-loving creatures in the hopeless night of poverty and sabbatarianism; more pitiful to see the reviving of their spirits at every deceptive sign of dawn, the expedients of poor, compromising Nature, her makeshifts with half-recreations and half-sufficient rest, in the lingering hope of a better future—to come only with the repose from which no factory-bell can awaken a sleeper, when after long years of

waning life, waning at last to a state of callous vegetation, Nature is reduced to the alternative of ending an evil for which she has no remedy.

But while the ebb of life alternates with a tide, the struggle against a natural instinct is the struggle of Prometheus against the vulture of Jove; in the intervals of torment the martyr may forget his misery, but the torturer returns, and the poisoned arrows of the interventor can bring only a temporary relief. Man can not conquer a God-sent instinct, though he may for a time defy it—with poison; the most incurable victims of intemperance are those who resort to stimulants less for the sake of intoxication than for the benumbing after-effect which helps them to stifle the voice of outraged Nature. It is a significant circumstance that the consumption of intoxicating poisons increases in times of famine and general distress; the Christian dogma of the reformatory value of misery has, indeed, been refuted by the most dreadful arguments of the world's history; the unhappiest nations are not only the most immoral, but the most selfish and the meanest in every ugly sense of the word: virtues do not flourish on a trampled soil. The same with individuals; injustice, disappointment, and bodily pain, can turn the noblest man into a querulous tyrant, a harmless kitten into a spiteful cat. Happiness, on the other hand, is the sunshine that decks the moral world with flowers; making earth a heaven would be the surest way of turning men into angels; the hardest heart will melt under the persistent rays of kindness and happiness. Happy children have no time to be wicked; it is not worth their while to waste the merry hours on vices. Genius, too, is a child of light; the Grecian worship of joy favored the development of every human science, while the monastic worship of sorrow produced nothing but monsters and chimeras; for to modern science Christianity bears about the same relation as the plague to the quarantine.

But, aside from all this, mirth has an hygienic value that can hardly be overrated while our social life remains what the slavery of vices and dogmas has made it. Joy has been called the sunshine of the heart, yet the same sun that calls forth the flowers of a plant is also needed to expand its leaves and ripen its fruits; and without the stimulus of exhilarating pastimes perfect bodily health is as impossible as moral and mental vigor. And, as sure as a succession of uniform crops will exhaust the best soil, the daily repetition of a monotonous occupation will wear out the best man. Body and mind require an occasional change of employment, or else a liberal supply of fertilizing recreations, and this requirement is a factor whose omission often foils the arithmetic of our political economists.

To the creatures of the wilderness affliction comes generally in the form of impending danger—famine or persistent persecution; and under such circumstances the modifications of the vital process seem to operate against its long continuance; well-wishing Nature sees her

purpose defeated, and the vital energy flags, the sap of life runs to seed. On the same principle an existence of joyless drudgery seems to drain the springs of health, even at an age when they can draw upon the largest inner resources; hope, too often baffled, at last withdraws her aid; the tongue may be attuned to canting hymns of consolation, but the heart can not be deceived, and with its sinking pulse the strength of life ebbs away. Nine tenths of our city children are literally starving for lack of recreation; not the means of life, but its object, civilization has defrauded them of; they feel a want which bread can only aggravate, for only hunger helps them to forget the misery of *ennui*. Their pallor is the sallow hue of a cellar-plant; they would be healthier if they were happier. I would undertake to cure a sickly child with fun and rye-bread sooner than with tidbits and tedium.

Mirth is a remedy; the remarkable longevity of the French aristocrats,* in spite of their dietetic and other sins, can with certainty be ascribed to the gayety of their pastimes; almost any mode of diversion is better than the deadly monotony of our sabbatarian machine-life; even excursion-trains have added years to the average longevity of our city populations. In a temperature of — 56° Fahr., Elisha Kane kept his men in good health by devoting a part of the long night to burlesques and pantomimes; but, as a sanitary precaution, dramaturgy was only collateral to the substitution of tea for grog; and the most striking illustration of the hygienic effect of merriment is therefore, perhaps, the experience of Dr. Brehm, the manager of the Hamburg Zoölogical Garden. Having noticed that the monkeys in the happy-family department generally outlived the solitary prisoners, he concluded to try the Swiss nostalgia-remedy, "fun and cider-punch"; but the liquid stimulants proved superfluous: the introduction of a grapple-swing and a few toys sufficed to reverse the shadow on the dial of death, and man by man the quadrumana recovered from a disease which evidently had been nothing but *ennui*, since the mortuary lists of the last decade showed an almost uniform death-rate throughout the year, except in midsummer, when the monkey-house could be thoroughly ventilated.

Men of a cheerful disposition are generally long-lived, and anything tending to counteract the influence of worry and discontent directly contributes to the preservation of health. Despair can paralyze the energy of the vital functions like a sudden poison, while the fulfillment of a long-cherished hope has effected the cure of many dis-

* E. g., Polignac, eighty-one years; Richelieu, eighty-three; Sainte-Pierre, seventy-eight; Chateaubriand, eighty; Lafayette, seventy-eight; Duke of Bassano, eighty-one; Corneille, eighty; Dumouriez, eighty-four; Palinet, eighty-five; Fontenelle, one hundred; Joinville, ninety-one; L'Enclos, eighty-nine; La Maintenon, eighty-four; Rochefoucauld, eighty; Villars, eighty-one; Sully, eighty-one; Montfaucon, eighty-six; Soult, eighty-two; Talleyrand, eighty-four.

eases; history abounds with examples of strong men dying of sheer grief,* as well as of a great success giving to others a new lease of life. Even hope can sustain the vital powers under severe trials; the appearance of a distant sail or a leeward coast has often restored the strength of shipwrecked sailors who would have succumbed to another hour of hopeless famine. A mere day-dream of a possible deliverance from toil or captivity prolongs the life of thousands who would not survive an awakening to the realities of their situation.

But "hope deferred" sickens the body as well as the soul; and, next to the happiness of a life whose labors are their own immediate reward, is the confident anticipation of a period of compensating enjoyments at the end of every day, of every week, and every year, or part of a year. With a few playthings the youngsters of the nursery will find pastimes enough, though even the youngest should have some corner of the house where they can feel quite at home; but the necessity of providing special times and modes of recreation begins with the day when a child is delivered to the taskmaster, when its employment during any considerable part of the twenty-four hours becomes laborious and compulsory. Children under ten should never be kept at school for more than three consecutive hours, unless the variety of the successive lessons forms itself a sort of recreation, as drawing after grammar, or writing alternating with "calisthenics" or vocal exercises. If the principal meal of the day is taken at noon, the mid-day recess should be extended to at least three hours; otherwise one hour is more than sufficient, especially where the recess sports are diverting enough to forget the schoolroom for a few minutes. The more completely a special train of thoughts can for a while be dismissed from the mind, with the more profit can it afterward be resumed, for the same reason that the successful practice of any bodily exercise requires a periodical relaxation of the strained muscles. But, if the instinct of rooks and savages can be trusted, the recreation-time, *par excellence*, is the evening hour; and with a little management young and old bondmen of drudgery might consecrate the end of every day to health-restoring sports. All schools ought to close at 4 P. M.; and, till we can enforce the eight-hours labor law, the societies for the prevention of cruelty should liberate at least the younger factory-slaves two hours before the sunset of a summer day, in order to give them a chance for a few minutes' recreation between supper and bedtime. "*Horas non conto, nisi serenas*" was the usual inscription of the Roman sun-dials, but the Arabs of the desert count time by nights instead of days; and for us, too, sunset is the beginning of the most pleasant and most play-inviting hour of the twenty-four; the day's work is done, no fear of interruption damps the merriment of the moment, and to the fatigue

* E. g., Isocrates, Kepler, Mehemet Ali, Bajazet, Politianus, Columbus, Maupertuis, Pitt, the two Napoleons, Nicholas I, Joseph II, Platen, Abd-el-Kader, Shamyl, Horace Greeley.

of boisterous sports the coming night offers the refuge of rest and sleep. For the same reason the compulsory somnolence of our Quaker-sabbath makes Saturday night the Saturnalia-time of many Christian nations; the Sunday laws have reduced them to amusements which can, and too often ought to, dispense with daylight, and in the larger cities apprentices and factory-boys have the alternative of joining in such night revels or postponing their amusements to the musical resurrection of the saints in light, for the free Saturday is unfortunately confined to primary schools and a few private seminaries. In German schools Saturday is at least a half-holiday; i. e., the scholars are dismissed at noon, and at once make for the fields and woods, except in winter, when the disciples of the Turnerhall assemble on the last afternoon in the week.

With our present helplessness against the lethargic influence of the midsummer heat, the conventional time of the long vacations is well selected, but, if a hoped-for diet and dress reform shall have taught us to pass the dog-days with comfort, it would be more sensible to divide the two months: four free weeks in June, in time for the first huckleberries and butterflies, and four in October—the best season for a long excursion to the paradise of a primitive mountain-range, nowadays about the only sanctuary of Nature where her worshipers can shake their shoulders free from the yoke of prejudice and escape from the atmosphere of hypocrisy to a higher and purer medium. For the children of the poor every city should have a *Kinder-park*—not a ceremonious promenade, with sacred groves and unapproachable grass-plots, but a public play-ground with shade-trees and swings, May-poles, gymnastic contrivances and a free bathing-house, and room for all the free menageries and music-halls which the Peabodies of the future might feel inclined to add. Inactivity is no recreation; we should not spend our leisure hours like machines, whose best relief is a temporary surcease of toil, but like living creatures of the God who intended that the joys of life should outweigh its sorrows. Let us provide healthful pastimes, or the victims of asceticism will resort to vices—dram-drinking, gambling, and secret sins—for even pernicious excitements become attractive as a relief from the insupportable dullness of a canting Quaker life.

Ennui has never made a human being better or more industrious; on the contrary, the hope of a merry evening would inspire a day-laborer with a good-humor and an energy unknown to the languid *resignados* of our present system. The confident expectation even of a physical pleasure imparts to the current of life an onward impulse that seems to react on the mind as well as on every function of the automatic organism; the first Napoleon, who enlivened the tedium of camp-life with Olympic festivities, and did not deem it below his dignity to make his own *maître de plaisir*, could in return rely on his men to endure fatigues that would have killed the barrack-slaves of

his enemies. It is not hard work that drives our young men to seek a Lethe in alcohol: we read of Grecian soldiers marching fifty miles a day in heavy armor; of hunters running down a wild-boar, and of teamsters yoking themselves to a car when their horses had broken down. Many of our New England boys, who go on a whaling cruise rather than die of *ennui*, would gladly consent to work, in the ancient sense of the word, if they could exchange their Pecksniff-day for a Grecian festival. The Aryan nations, too, had their sacred days and sacred rites, but their Nature-worship was the mist that rises from the woods and meadows, and blends with the ethereal hues of the sky; the Hebrew priestcraft dogma is a poison-cloud which for centuries has darkened the light of the sun and blighted the fairest flowers.

In choosing the mode of a child's recreations, it should be borne in mind that their main purpose is to restore the tone of the mind and its harmony with the physical instincts by supplying the chief deficiencies of our ordinary employment. For a hard-working blacksmith, fun, pure and simple, would be a sufficient pastime, while brain-workers need a recreation that combines amusement with physical exercise—the unloosening of the brain-fiber with the tension of the muscles. Emulation and the presence of relatives and schoolmates impart to competitive gymnastics a charm which a spirited boy would not exchange for the passive pleasure of witnessing the best circus-performance. Wrestling, lance-throwing, archery, base-ball, and a well-contested foot-race, can awaken the enthusiasm of the Grecian *palæstra*, and professional gymnasts will take the same delight in the equally healthful though less dramatic trials of strength at the horizontal bar. But, on the play-ground, such exercises should be divested from the least appearance of *being a task*—even children can not be happy on compulsion.

There is also too much in-door and in-town work about the present life of our schoolboys. Encourage their love of the woods; let us make holidays a synonym of picnic excursions, and enlarge the definition of camp-meetings; of all the known modes of inspiration, forest air and the view of a beautiful landscape are the most inexpensive, especially from a moral standpoint, being never followed by a splenetic reaction. A ramble in the depths of a pathless forest, or on the heights of an Alpenland, between rocks and lonely mountain-meadows, opens well-springs of life unknown to the prisoners of the city tenements.

But the chief curse of our in-door life is, after all, its dullness; and its direct antidote merriment, therefore the chief point about all real recreations. Fun and laughter have become the most effective cordials of our materia medica, and their promotion a most important branch of the science of happiness. There is no such thing as genuine frolic in the stifling atmosphere of a stove-room; the shady lawn in summer and the open hall in winter make a better play-ground than the stuffy nurs-

ery; but freedom from restraint is a still more essential element of mirth. Even in the despotic countries of the Old World the representative of the Government attends the public *fêtes* in disguise, and, if the schoolmaster wants to watch the recess-sports of his pupils, let him do so unobserved; if you can trust your children at all, trust them not to abuse the freedom of their recreations, or else conduct your surveillance as unobtrusively as possible. Children detest ceremonies; in our etiquette-ridden towns too many boys are aliens under their fathers' roof; give them one hour in the day and one corner in the house where they are really at home, where they can feel that the permission to enjoy themselves is granted as a right rather than as a concession to the foibles of youth. If I had to board my children in an old hull, like Anderson's sea-shell peddler, I would let them store their toy-shells in the caboose, and keep it sacred from the intrusion of the forecastle folk, to let my little ones know that the believers in the divinity of joy, though in a sad minority in this pessimistic world, have rights and perquisites which I mean to maintain against all comers.

It does not cost much to make the little folks happy; time, and permission to use it, is all the most of them ask; but make them sure that the pursuit of happiness is not a contraband affair, but a legitimate and praiseworthy business. Nor can it do any harm to let them accumulate a little stock in trade—marbles, tops, dolls, and magic lanterns, and, if possible, a few pets; in winter-time, and for the bigger boys, a private menagerie of squirrels and gophers is a better aid to domestic habits than a hundred interviews with the home-missionary. Connive at a snowball-fight or a torn hat; and be sure that a pair of skates, fishing-tackle, and a base-ball outfit are a better investment than a medicine-chest. Make your children happy; all Nature proclaims the plan of a benevolent Creator; let them feel that their life is in harmony with that plan—that existence has a positive value, an attraction that would remain, though the fear of death were removed.

And, above all, let no cloud of superstition darken the sunshine of your Sundays; and, in countries where the knell of the church-bells drives your children from the play-grounds of the city, take them out to the woods and mountains, and let them worship the Creator in his grandest temple; teach them to love his day by making it the happiest day in the week. Or, disregard the bells and brave the consequences: till we can repeal the sabbath laws, let us defy them in every way and at any risk; in dealing with the despotism of the mythology-mongers, legal obligations are out of the question; the right of Nature enters the lists against the right of brutal force leagued with imposture.

THE BLOOD AND ITS CIRCULATION.

By HERMAN L. FAIRCHILD.

THE main facts of blood circulation have been known only two hundred and fifty years. This would be surprising if we were not aware that most of our certain knowledge in natural history, including many truths of easier discovery than the circulation of the blood, has been gained within the last one hundred years. And, indeed, the blood and its movements are not yet fully understood. Several points which, at first thought, would seem of easy solution, are matters in dispute or confessed mysteries. The purpose of this article is, not to publish new truth or discuss difficult points, but to compactly present the fundamental and interesting facts relating to the circulation in all animals.

The necessity of a circulating nutritive fluid lies in the localizing of the process of digestion. In proportion as digestion and absorption of food become specialized and restricted to certain parts, circulation becomes more important in order to convey that food to the tissues, and carry from the tissues the worn-out material. To maintain the character of the fluid, it must itself undergo constant change, and hence the excretory processes—respiration being the most urgent—which increase the necessity for movement of the fluid. Circulation of the nutritive fluid is the immediate function for upbuilding and repairing the body. It harmonizes the several vegetative functions, and should be regarded as the primary function, to which all the others are subservient.

The amœba, sponge, and tapeworm have no blood; they have no necessity for it, as they are destitute of digestive organs, their food being in immediate contact with all parts of the body: or, we might regard their blood as simply the water or fluid in which the animal is immersed. In animals possessing the simplest digestive cavities, as the jelly-fish and sea-anemone, the blood is merely the dissolved food, corresponding to the *chyme* of higher animals. In the starfish, sea-urchin, and other invertebrates, having a complete and distinct stomach, the blood is *chyle;* while in vertebrates the blood is a distinct fluid, chemically very complex, difficult of analysis, and not perfectly understood: structurally, it is essentially the same in all animals—a clear fluid containing organic particles.

The blood contains all the nourishment which supports the various tissues of the whole structure. It may properly be regarded as the fundamental tissue, and is well named in the French *chair coulant*—running flesh. It changes rapidly by eating, exercise, and any influence which affects the supply of nutriment or the waste of the body. It is derived primarily from the new food, received in the higher ani-

mals chiefly through the lacteals and veins of the stomach; secondly, from the waste of the body received through the lymphatics and thoracic duct; and, thirdly, through respiration, which supplies oxygen. The amount of solid matter seems to bear a proportion to the amount of flesh in the diet and to the temperature of the animal, being greater in the carnivorous and warm-blooded animals.

In color, the blood of all vertebrates is red, excepting that of the

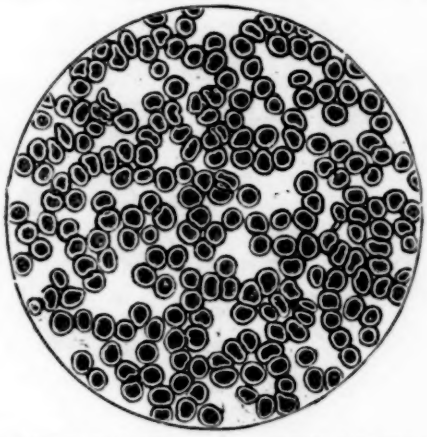

FIG. 1.—HUMAN BLOOD-CORPUSCLES; magnified 370 diameters.

amphioxus, the lowest animal of the sub-kingdom, which is colorless. In the muscles of fishes it is also white. In the invertebrates the blood is of various colors, but commonly white, on account of which fact they were formerly supposed to be destitute of blood.

Microscopic examination of the blood of a vertebrate animal shows that the color is due to an immense number of red particles floating in a watery fluid. But the shape and size of these corpuscles vary in the different groups of vertebrates, and in different species. In man, and all mammals excepting the camel tribe, the red corpuscles are biconcave disks. In the camel they are elliptical. The corpuscles in all other vertebrates are nucleated, or have a thickened center. Those of birds, reptiles, and amphibians are elliptical, while those of fishes are discal, elliptical, or angular.

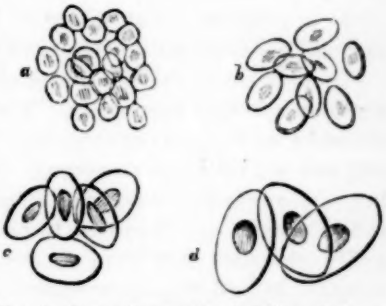

FIG. 2.—BLOOD-CORPUSCLES (relative size). *a*, Man; *b*, Blenny; *c*, Frog; *d*, Newt.

The size of the red blood-corpuscles bears little relation to the size of the animal, except within the natural groups, as the orders of mam-

mals and the class of birds. The largest are found in the amphibians, those of the *proteus* being $\frac{1}{400}$ of an inch in diameter. The smallest are found in the musk-deer, being $\frac{1}{12000}$ of an inch. Those of the ostrich are $\frac{1}{1600}$ of an inch, and of the humming-bird $\frac{1}{3000}$ of an inch. Yet this tiniest of vertebrates equals, in the size of its blood-corpuscles, the largest of living creatures, the bulky whale. Those of man are from $\frac{1}{3000}$ to $\frac{1}{3200}$ of an inch. The value of microscopic measurements of blood-corpuscles, as evidence in legal cases, has been

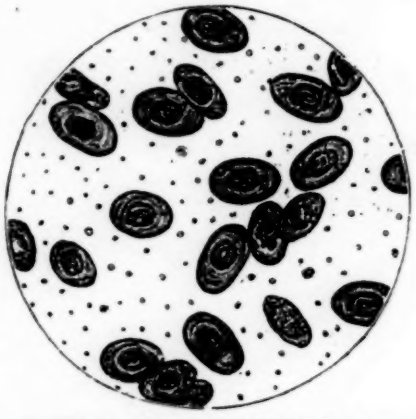

FIG. 3.—BLOOD CORPUSCLES OF THE FROG; magnified 370 diameters, showing the nucleus.

much overrated. It is quite impossible to distinguish human blood from that of the dog, and, without very extensive measurements, from that of some other mammals.

These red corpuscles are frequently larger than the capillary tubes through which they have to pass, but, on account of their elasticity, they squeeze through and afterward regain their shape.

It is estimated that a drop of human blood contains one million corpuscles—a late authority says five millions—in a cubic millimetre.

In addition to the red corpuscles of the vertebrates, all true blood contains colorless corpuscles. These are nucleated in the vertebrates, mollusks, and higher articulates. They are usually smaller than the red, and not nearly so numerous. They vary rapidly in number according to changes in the body or blood, and may bear a proportion to the red of one in one thousand to one in three hundred. Although generally globular, they have no fixed shape, but have amœboid movements. Indeed, the resemblance is so close between the amœba and these white corpuscles, that Professor Huxley, in defining the amœba, says it is structurally "a mere colorless blood-corpuscle leading an independent life." And again he says: "Leaving out the contractile vacuole, the resemblance of an *amœba* in its structure, manner of moving, and even of feeding, to a colorless corpuscle of the blood of one of the higher animals is particularly noteworthy"; also in a foot-note

to this, "contractile vacuoles have been observed in the colorless blood-corpuscles of *amphibia* under certain conditions." Is it possible that the human body is an aggregation or colony of low individuals, something like a sponge? It is believed that the red corpuscles are produced from the white, being only their modified nuclei. They are more numerous in the capillaries and veins. The death and reproduc-

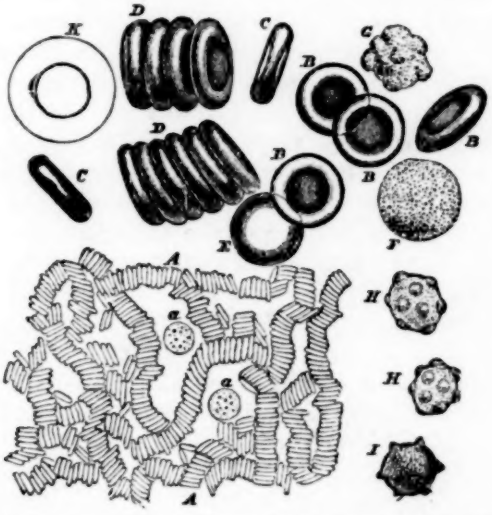

FIG. 4.—RED AND WHITE CORPUSCLES OF HUMAN BLOOD GREATLY MAGNIFIED. A, red corpuscles, lying in rows like rolls of coin; at *a* and *a* are seen two white corpuscles. B, red corpuscles more highly magnified, seen in face; C, the same in profile; D, the same in rows more highly magnified; E, a red corpuscle swollen into a sphere by absorption of water. F, a white corpuscle magnified same as B. G, the same, throwing out some blunt processes; K, the same, treated with acetic acid, showing nucleus, magnified the same as D. H, red corpuscles puckered or crenate all over; I, the same, at the edge only.

tion of the blood-corpuscles are rapid and constant. Dr. Draper estimates that twenty millions die at every breath. In transfusion of the blood of a bird into a mammal, the bird-corpuscles soon disappear.

Upon exposure to the air the fibrine of the blood hardens, and, entangling the corpuscles, forms the *clot*, leaving a yellowish liquid called *serum*. The composition of the blood may be graphically shown as follows:

Liquid blood	Corpuscles	Colored, Colorless	Clot	Coagulated blood.
	Plasma, or Liquor sanguinis	Fibrine		
		Serum	Albumen	
			Serosity = water and salts	

Coagulation serves in nature the purpose of stopping wounds. It is providentially more rapid in the lower animals, as they have no artificial means of arresting the flow of flood; and quite instantaneous in insects. What prevents the blood from coagulating during life, or in the blood-tubes, is unsettled. It can be prevented by salt.

The temperature of the blood depends upon the rapidity with

which the blood is oxidized; and, within natural orders, it has a relation to the activity of the animal. For example, that of the swallow is 111°, hen 109°, gull 100°; among mammals, squirrel 105°, cat 101°, dog 99°, man 98°. The animals called cold-blooded are only relatively so, for fishes and reptiles have a temperature somewhat above that of the water or air in which they live. Even the lower creatures are slightly warmer than the surrounding medium.

The weight of the blood, which is always greater than that of water, depends, of course, upon the amount of solid matter and the abundance of the corpuscles. In man, the red corpuscles constitute one third to a little less than one half the mass of the blood. The blood of birds has the largest proportion; and it appears that the temperature bears a relation to the amount of solid matter.

The amount of blood is greater in warm-blooded animals; and the *proportion* of blood to the size of the body increases with the size. The blood of man is by weight about one thirteenth the weight of the body. The dog has blood equal to one fifteenth its body-weight; rabbit, one eighteenth; cat, one twenty-first. The amount of blood in the elephant and the whale has not been determined; but the heart of the whale is three feet in diameter.

The operation of transfusing the blood of a living animal into the vessels of another, or of one that is dying, was known in ancient times, and has been practiced at intervals for the last three hundred years. Extravagant hopes concerning it were formerly entertained. It was believed that diseases might be cured, impaired reason restored, old age deferred, and even the dead returned to life. In late years the eminent Brown-Séquard states that a dead dog was by this means restored to life for twelve hours; but the experiment has never been confirmed, and doubtless the animal was not dead, as supposed. It is also stated that a maniac was restored to reason by the blood of a calf.

In modern medical science, the transfusion of blood has become a well-recognized operation for cases of exhaustion from simple loss of blood. For this it is frequently practiced, and with success in the majority of cases. For general weakness and disease it has sometimes been used, but has not proved reliable.

The amount of blood used in transfusion is usually a very few ounces, sometimes only one or two drachms — rarely ten or more ounces; a small quantity is safer. The blood of a different species of animal is considered dangerous when used in large quantity. Venous blood is preferred, and may or may not be defibrinated.

Pure milk has been successfully used instead of blood; and even artificial mixtures are employed. Richardson kept a monkey alive for several weeks by a daily injection of an artificial blood.

The veins of the extremities are generally selected for the operation, they being less likely to admit air, which might be fatal by causing coagulation.

From what has already been stated as the purpose of circulation, we should not expect to find any circulation in those animals which are destitute of a separate digestive cavity; and in such we do not discover a true blood-circulation. But it would appear that no animal is entirely without the power of distributing its food to the parts of the body. In the amœba this is accomplished by the movements of the protoplasmic body, whereby the portions which have enwrapped and dissolved food-particles are blended with the less nourished parts. The "contractile vesicles" of the amœba may also have to do with the distribution of nourishment, though they are usually regarded as respiratory or excretory in function.

Next to this, in simplicity, is the prolongation of the digestive cavity for the distribution of food. This is found in various animals of different classes. The jelly-fish has a system of four canals, radiating from the imperfect stomach, and uniting with a circular canal at the margin of the body. We may regard this as the earliest development of organs for conveying nutriment. A similar condition exists in the anemone; and spiders have prolongations of the stomach in addition to their circulating organs.

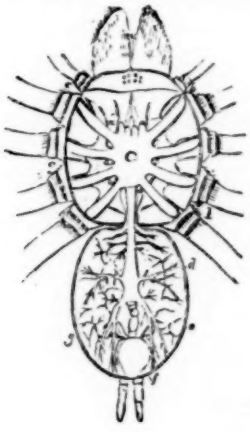

Fig. 5.

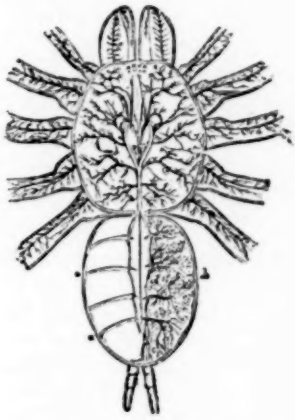

Fig. 6.

Circulation of the Spider Mygale Blondii. Fig. 5.—The stomach, with its cæca and the remainder of the alimentary canal, with the liver and Malpighian tubes. Fig. 6.—Heart and arterial vessels.

True circulation is found only with a complete separation of the digestive cavity from the visceral or general body cavity. In many invertebrates there is simply a flux and reflux of nutritive fluid in this visceral cavity, but no special circulating vessels. This is the condition in the bryozoa, the lowest of mollusks, in the rotifera, and in the larvæ of certain myriapods and insects. In these the fluid is more the nature of chyle, and is called the chylaqueous fluid.

The "circulating system is gradually developed as an offset of the visceral cavity." This is shown by the low ascidian mollusks, in

which there is a sinus system prolonged from the visceral cavity, but freely communicating with it. In this system the chylaqueous fluid flows alternately in either direction, being propelled by a pump or rudimental heart, which is only a muscular portion of one of these sinuses. The same condition is found in some low crustaceans and arachnids, and in the larvæ of certain insects.

In former articles the sea-urchin has been noticed as the lowest possessor of true teeth and stomach, and we now have to award it the added honor of the first distinct heart and blood-vessels.

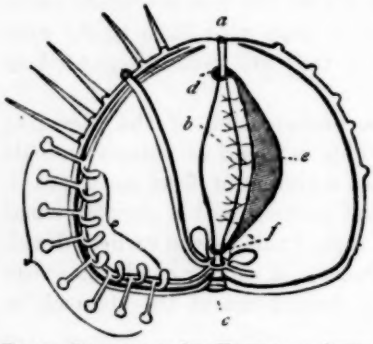

FIG. 7.—DIAGRAM OF SEA-URCHIN. *a*, Anus; *b*, Stomach; *c*, Mouth; *e*, Heart, which by vascular rings encircles the alimentary canal at *d* and *f*.

The more highly organized invertebrates have a muscular heart and true arteries. But the blood always enters the visceral cavity before returning to the heart. In other words, there is no closed current in the invertebrates, the system of circulating vessels being in direct communication with the body cavity. Regarding the circulation of the lower invertebrates, there is still much uncertainty, as various sets of vessels are found in different groups, the purpose of which is obscure, and their relation to the blood-circulation a matter of investigation. The great variety in the circulation of the many groups of invertebrates renders a detailed description impossible. It will be consonant with the present purpose to briefly describe only a few typical forms.

The typical system of the articulates is simply a segmented vessel

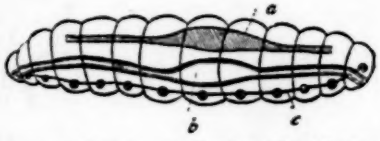

FIG. 8.—DIAGRAM OF ARTICULATE ANIMAL. *a*, Heart or Blood System; *b*, Digestive System; *c*, Nervous System.

lying lengthwise in the back of the animal. This dorsal tube, trunk, or "heart," is open at both ends, and has openings along the sides, guarded by valves. The chylaqueous fluid fills the body cavity, bathing the heart and all the viscera. A puncture of the skin alone allows the blood to issue. The walls of the tubular heart are muscular and pulsatile. When the heart expands, the nutritive fluid is drawn in at the hinder end and lateral apertures, and upon contraction it is forced forward and escapes at the forward end, being prevented by valves from flowing backward or escaping laterally. The

fluid finds its way backward through the lacunæ or passages between the tissues and viscera. The dorsal vessel prevents the stagnation of the fluid.

In the myriapods the dorsal trunk has as many segments as there are joints of the body. One of the millepeds has not less than one hundred and sixty. Centipeds have generally twenty-one segments, and besides the pair of valves for each joint there is given off a pair of arteries. These unite to form a ventral tube. Insects have the heart segmented only in the abdomen, and never more than eight segments. An arterial prolongation of the trunk as a simple tube extends to the head.

As spiders and scorpions have localized breathing-sacs, they require a respiratory circulation. This is secured, not by special tubes, but by the passage of the blood, on its return to the heart, through venous sinuses or special passages between the internal organs.

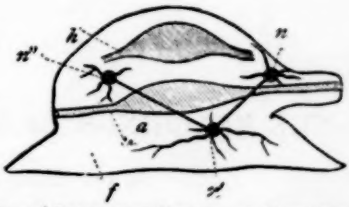

FIG. 9.—DIAGRAM OF MOLLUSK. *a*, Alimentary Canal; *h*, Heart; *n*, *n'*, *n''*, Nervous Ganglia.

The best heart among articulates is possessed by the crustaceans, the largest, though not the highest, animals of the sub-kingdom. Crabs and lobsters have a concentrated heart, a short, fleshy sac, with great propelling power, which sends the blood by several branching arteries to the parts of the body. We now find a concentration of the power which had been previously diffused in a long tube.

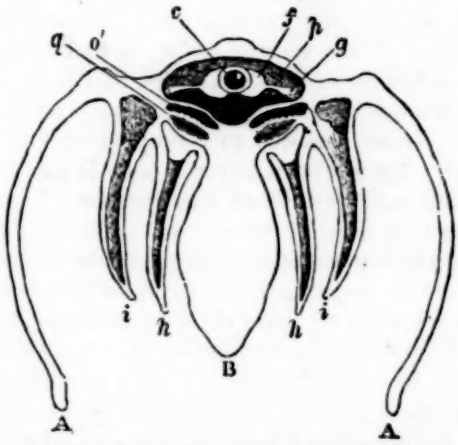

FIG. 10.—CROSS-SECTIONAL DIAGRAM OF A FRESH-WATER MUSSEL. *f*, Ventricle; *g*, Auricles; *c*, Rectum; *p*, Pericardium; *h*, *i*, Gills; B, Foot; A, A, Mantle or Skin.

As the mollusks are mostly so sluggish that their circulation has little aid from the movements of the body, they require a more pow-

erful pump. In the higher mollusks the heart has generally two cavities—an auricle for receiving the blood and a ventricle for propelling it. The bivalve mollusks have generally two auricles. In the mollusks we discover a well-developed capillary system, but the venous or return circulation is still partly lacunar. The heart of invertebrates is always systemic—it forces the blood to the body, not to the breathing-organs. But some of the cephalopod mollusks, the so-called devil-fishes, have contractile cavities at the bases of the gills, which act the part of a pulmonary heart, forcing the blood through the breathing-organs on its way to the true heart. These accessory hearts are called *branchial hearts.*

[*To be continued.*]

THE TEACHINGS OF MODERN SPECTROSCOPY.*

By Dr. ARTHUR SCHUSTER, F. R. S.

A SCIENCE, like a child, grows quickest in the first few years of its existence; and it is therefore not astonishing that, though twenty years only have elapsed since Spectrum Analysis first entered the world, we are able to speak to-day of a modern spectroscopy, with higher and more ambitious aims, striving to obtain results which shall surpass in importance any of those achieved by the old spectroscopy, to the astonishment of the scientific world.

A few years ago the spectroscope was a chemical instrument. It was the sole object of the spectroscopist, to find out the nature of a body by the examination of the light which that body sends out when it is hot. The interest which the new discovery created in scientific and unscientific circles was due to the apparent victory over space which it implied. No matter whether a body is placed in our laboratory or a thousand miles away—at the distance of the sun or of the farthest star—as long as it is luminous and sufficiently hot, it gives us a safe and certain indication of the elements it is composed of.

To-day, we are no longer satisfied to know the chemical nature of sun and stars; we want to know their temperature, the pressure on their surface; we want to know whether they are moving away from us or toward us; and, still further, we want to find out, if possible, what changes in their physical and chemical properties the elements with which we are acquainted have undergone under the influence of the altered conditions which must exist in the celestial bodies. Every sun-spot, every solar prominence, is a study in which the unknown quantities include not only the physical conditions of the solar surface,

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but also the possibly changed properties, under these conditions, of our terrestrial elements. The spectroscope is rapidly becoming our thermometer and pressure-gauge; it has become a physical instrument.

The application of the spectroscope to the investigation of the nature of celestial bodies has always had a great fascination to the scientific man as well as to the amateur; for in stars and nebulæ one may hope to read the past and future of our own solar system. But it is not of this application that I wish to speak to-day.

As there is no other instrument which can touch the conditions of the most distant bodies of our universe, bodies so large that their size surpasses our imagination, so is there no other instrument which equals it in the information it can yield on the minute particles at the other end of the scale, particles which in their turn are so small that we can form no conception of their size or number. The range of the spectroscope includes both stars and atoms, and it is about these latter that I wish to speak.

The idea that all matter is built up of atoms, which we can not further divide by physical or chemical means, is an old one. As a scientific hypothesis, however—that is, an hypothesis which shall not only qualitatively, but also quantitatively, account for actual phenomena—it has only been worked out in the last thirty years. The development of molecular physics was contemporaneous with that of spectroscopy, but the two sciences grew up independently. Those who strove to advance the one paid little attention to the other, and did not trouble to know which of their conclusions were in harmony, which in discordance, with the results of the sister science. It is time, I think, now that the bearing of one branch of inquiry on the other should be pointed out: where they are in agreement, their conclusions will be strengthened, while new investigations will lead to more perfect truths where disagreement throws doubt on apparently well-established principles.

What I have ventured to call modern spectroscopy is the union of the old science with the modern ideas of the dynamical theory of gases, and includes the application of the spectroscope to the experimental investigation of molecular phenomena, which without it might for ever remain matters of speculation or of calculation.

A body, then, is made up of a number of atoms. These are hardly ever, perhaps never, found in isolation. Two or more of them are bound together, and do not part company as long as the physical state of the body remains the same. Such an association of atoms is called a molecule. When a body is in the state of a gas or vapor, each molecule for the greater part of the time is unaffected by the other molecules in its neighborhood, and therefore behaves as if these were not present. The gaseous state, then, is the one in which we can best study these molecules. They move about among each other, and

within each molecule the atoms are in motion. Each atom, again, has its own internal movement. But, if the world were made up of atoms and molecules alone, we should never know of their existence; and, to explain the phenomena of the universe, we must recognize the presence of a continuous universal medium penetrating all space and all bodies. This medium, which we call the luminiferous ether, or simply the ether, serves to keep up the connection between atoms or molecules. All communications from one atom to another, and from one molecule to another, are made through this ether. The internal motions of one atom are communicated to this medium, propagated through space, until they reach another atom; attraction, repulsion, or some other manifestation takes place; and, if you examine any of the changes which you see constantly going on around you, and follow it backward through its various stages, you will always find the motion of atoms or molecules at the end of the chain.

The importance of studying the motion of molecules is therefore clear; and it is the special domain of the modern spectroscopy to investigate one kind of these motions.

When a tuning-fork or a bell is set in vibration, its motion is taken up by the surrounding air, waves are set up, they spread and produce the sensation of sound in our ears. Similarly, when an atom vibrates, its motion is taken up by the ether, waves are set up, they spread, and if of sufficient intensity produce the sensation of light in our eyes. Both sound and light are wave-motions. A cursory glance at a wave in water will lead you to distinguish its two most prominent attributes. You notice at once that waves differ in height. So the waves both of light and sound may differ in height, and to a difference in height corresponds a difference in the intensity of the sound you hear or of the light you see. The higher the wave the greater its energy, the louder is the sound or the brighter is the light. But, in addition to a difference in height, you have noticed that in different waves the distance from crest to crest may vary. The distance from crest to crest is the length of the wave, and waves not only differ in height but also in length. A difference in the length of a wave of sound corresponds to a difference in the pitch of the sound; the longer a sound-wave is, the lower is the tune you hear. In the case of light a difference in the length of the wave corresponds to a difference in the color you see. The longest waves which affect our eyes produce the sensation of red, then follow orange, yellow, green, blue, and the shortest waves which we ordinarily see seem violet. If a molecule vibrates, it generally sends out a great number of waves which vary in length. These fall together on our retina, and produce a compound sensation which does not allow us to distinguish the elementary vibrations, which we want to examine. A spectroscope is an instrument which separates the waves of different lengths before they reach our retina; the elementary vibrations, after having passed through a spectroscope, no longer

overlap, but produce their impressions side by side of each other, and their examination and investigation is therefore rendered possible.

The elements of spectroscopy will be familiar to most of you, but you will forgive me if I briefly allude to some points, which, though well known, are of special importance in the considerations which I wish to bring before you to-night.

When a body is sufficiently hot it becomes luminous, or, to speak in scientific language, the vibrations which are capable of producing a luminous sensation on our retina are increased in intensity as the temperature is raised, until they produce such a sensation. By means of a strong electric current I can in the electric lamp raise a piece of carbon to a high temperature. When looked at with the unaided eye it seems whitehot, but, when I send the rays through a prism and project them, as I do now, on a screen, you see a continuous band of light. This fact we express by saying that the spectrum of the carbon poles in the electric lamp is a continuous one. You see side by side the different colors known to you by the familiar but incorrect name of "the rainbow-colors"; and the experiment teaches you that the carbon pole of the electric lamp sends out rays in which all wave-lengths which produce a luminous sensation are represented.

But, if now I introduce into the electric arc a small piece of a volatile metal, you see no longer a continuous band of light. The band is broken up into different parts. Narrow bands or lines of different colors are separated by a space sometimes black, sometimes slightly luminous. The metal has been converted into vapor by the great heat of the electric current, and the vibrations of its molecules take place in distinct periods, so that the waves emanating from it have certain definite lengths. If the molecule could only send out one particular kind of waves, I should in its spectrum only see one single line. We know of no body which does so, though we know of several in which the possible periods of vibration are comparatively few; the spectrum of these will, therefore, contain a few lines only. Thus we have two different kinds of spectra, continuous spectra and line-spectra. But there is a certain kind intermediate in appearance between these two. The spectra of "fluted bands," as they are called, appear, when seen in spectroscopes of small dispersive powers, as made up of bands, which have a sharp boundary on one side and gradually fade away on the other. When seen with more powerful instruments, each band seems to be made up of a number of lines of nearly equal intensity, which gradually come nearer and nearer together as the sharp edge is approached. This sharp edge is generally only the place where the lines are ruled so closely that we can no longer distinguish the individual components. The edge is sometimes toward the red, sometimes toward the violet, end of the spectrum. Occasionally, however, the fluted bands do not show any sharp edge whatever, but are simply made up of a series of lines which are, roughly speaking, equi-

distant. No one who has seen a spectrum of fluted bands can ever fail to distinguish it from the other types of spectra which I have described.

What, then, is the cause for the existence of these different types? The first editions of text-books in which our science was discussed stated that a solid or liquid body gave a continuous spectrum, while a gaseous body had a spectrum of lines; the spectra of bands were not mentioned. The more recent editions give a few exceptions to this rule, and the editions which have not appeared yet, will—so I hope, at least—tell you that the state of aggregation of a body does not directly affect the nature of the spectrum. The important point is not whether a body is solid, liquid, and gaseous, but how many atoms are bound together in a molecule, and how they are bound together. This is one of the teachings of modern spectroscopy. A molecule containing a few atoms only gives a spectrum of lines. Increase the number of atoms, and you will obtain a spectrum of fluted bands; increase it once more, and you will obtain a continuous spectrum. The scientific evidence for the statements I have made is unimpeachable. In the first place, I may examine spectra of bodies which I know to be compound. Special precautions often are necessary to accomplish this purpose, for too high a temperature would invariably break up the compound molecule into its more elementary constituents. For some bodies I may employ the low temperature of an ordinary Bunsen burner. With others, a weak electric spark taken from their liquid solutions will supply a sufficient quantity of luminous undecomposed matter to allow the light to be analyzed by a spectroscope of good power. The spectrum of a compound body is never a line-spectrum. It is either a spectrum of bands or a continuous spectrum. The spectra of the oxides, chlorides, bromides, or iodides of the alkaline earths, for instance, are spectra of fluted bands. All these bodies are known to contain atoms of different kinds—the metallic atoms of calcium, barium, or strontium, and the atoms of chlorine, bromine, iodine, or oxygen.

But to obtain these spectra of bands we need not necessarily have recourse to molecules containing different kinds of atoms. Elementary bodies show these spectra, and we must conclude therefore that the dissimilarity of the atoms in the molecule has nothing to do with the appearance of the fluted bands. Similarity in the spectrum must necessarily be due to a similarity in the forces which bind the atoms together, and this at once suggests that it is the compound nature of the molecule which is the true cause of the bands, but that the molecule need not be necessarily a compound of an atom with an atom of different kind, for it may be a compound of an element with itself. We have ample proof that this is the true explanation of the different types of spectra. I shall presently give you a few examples in support of the view which is now nearly unanimously adopted by spectroscopists.

I have hitherto left unmentioned one important method of investigating the periods of molecular vibrations, a method which is applica-

ble to low temperatures. If I have a transparent body and allow light sent out by a body giving a continuous spectrum to fall through it, I often observe that the transparent body sifts out of the light falling through it certain kind of rays. Spectra are thus produced which are called absorption spectra, because the body which is under examination does not send out any light, but absorbs some vibrations which are made to pass through it. It is an important fact that a molecule absorbs just the rays which it is capable itself of sending out. I can therefore investigate the spectrum of a body just as well by means of the absorption it produces as by means of the light which it sends out.

Vapors like bromine or iodine examined in this way give us a spectrum of fluted bands. A powerful spark in these gases gives, however, a line-spectrum. Here, then, a change of spectrum has taken place. The same body at different temperatures gives us a different spectrum, and the change which takes place is the same as that observed in the spectrum of a compound body the moment the temperature has risen sufficiently to decompose that body. I conclude from spectroscopic observations, therefore, that the molecules of bromine and iodine just above their boiling-point are complex molecules, which are broken up at the temperature of the electric spark. At high temperatures the molecules of these bodies contain a smaller number of atoms, and it follows from this that the gases must be lighter or that their density must be smaller. These conclusions, which on spectroscopic grounds have been definite and clear for some years, have recently, by independent methods, been confirmed by Victor Meyer and others. It has been directly proved that at high temperatures the molecules of iodine and bromine contain a smaller number of atoms than they do just above their boiling-point. In other cases the change of density has not been directly proved, only because these necessary measurements are difficult or even impossible at very high temperatures, but we may be perfectly sure that chlorine, as well as the metallic vapors of silver, sodium, potassium, etc., which show an analogous change of their spectra, will ultimately be proved to undergo a change of density at high temperatures.

As we can trace the change from a line-spectrum to a band-spectrum taking place simultaneously with an increase of density, so may we follow the change from a band-spectrum to a continuous spectrum indicating the formation of a molecule still more complex.

Sulphur-vapor, at a temperature just above its boiling-point, contains three times the number of atoms in one molecule that it does at a temperature of 1,000° Centigrade. The spectrum of sulphur-vapor observed by absorption is continuous when the heavier molecule only is present. At the higher temperatures, when each molecule is decomposed into three, the spectrum belongs to the type of fluted band-spectra. From the cases in which we can thus prove the change in the spectra and in the densities to go on simultaneously, we are justi-

fied in concluding that also in other cases, where no such change of density has yet been observed, it yet takes place; and it is not a very daring generalization to believe that a change in spectra is always due to a change in molecular arrangement, and generally, perhaps always, accompanied by a change in the number of atoms which are bound together into one molecule.

With regard to the well-known statement that solids and liquids give continuous spectra, while gases give line-spectra, it must be remarked that metallic vapors show in nearly all cases a continuous spectrum before they condense. Oxygen gives a continuous spectrum at the lowest temperature at which it is luminous. Examining liquids and solids by the method of absorption, we find that many of them show discontinuous spectra, presenting fairly narrow bands. It is not denied that the nearness of molecules does not affect the spectrum. It may render the bands more wide and indistinct at their edges, but its influence is more of a nature which in gas spectra is sometimes observed at high pressures when the lines widen, and does not consist of an alteration in type. Though in a solid or liquid body the molecules are much nearer together, they are less mobile; and hence the number of actual collisions need not be necessarily much increased. The fact that a crystal may show a difference in the absorption spectrum according as the vibrations of the transmitted light take place along or across the axis, shows, I think, that mutual impacts can not much affect the vibrations, but that each molecule, at least in a crystal, must be kept pretty well in its place.

We have divided spectra into three types, but in all attempts at classification we are met by the same difficulty. The boundaries between the different types are not in all cases very well marked. Every one will be able to distinguish a well-defined band-spectrum from a line-spectrum, but there are spectra taking up intermediate positions both between the line- and band-spectra and between band-spectra and continuous spectra. With regard to these it may be difficult to tell to which type the spectrum really belongs. It may happen that a change of spectrum takes place, the spectrum retaining its type; but in these cases, as a rule, the more complex molecule will have a spectrum approaching the lower type, although it may not actually belong to that lower type. To be perfectly general, we may say that a combination of atoms always produces an alteration in the spectrum in the direction of the change from the line-spectrum, through the band-spectrum to the discontinuous spectrum.

If we accept the now generally received opinion as to the cause of the different types of spectra, we may obtain information on molecular arrangement and complexity where our ordinary methods fail. At high temperatures, or under much diminished pressure, measures of density become difficult or impossible; and it is just in these cases that the spectroscope furnishes us with the most valuable information.

If we find three spectra of nitrogen and the same number for oxygen, we must accept the verdict, and conclude that these gases can exist in three different allotropic states.

Among the remarkable phenomena observed in vacuum-tubes, perhaps not the least curious is the spectrum observed at the negative pole, which in several cases is only observed there, and under ordinary circumstances in no other part of the tube. Both oxygen and nitrogen have a spectrum which is generally confined to the negative glow. Some years ago I tried to prove that also in these cases we have only to deal with a special modification of the gases which, curiously enough, only exists near the negative pole, and is broken up and decomposed in every other part of the tube. The experiments I then made seem to me to prove the point conclusively. After a current of electricity had passed through the tube for some time in one direction, the current was suddenly reversed; the negative pole now became positive, but the spectrum still was visible for some time in its neighborhood, and only gradually disappeared. This experiment shows that the spectrum may exist in other parts of the tube, and that it is therefore due to a peculiar kind of molecule, and not to anything specially related to electric phenomena taking place in the neighborhood of the negative pole. Other experiments supported this view.

The classification of spectra, according to the complexity of the vibrating molecule, is of great theoretical importance; for by its means we may hope to obtain some information on the nature of the forces which bind together the atoms into one molecule. Our whole life is a chemical process, and a great part of the mysteries of Nature would be cleared up if we could gain a deeper insight into the nature of chemical forces. I believe no other line of investigation to be as hopeful in this respect as the one which examines directly the vibrations of the molecules which take place under the influence of these chemical forces. If we could find a connection between the vibrations of a compound molecule and the vibrations of the simpler elements which it contains, we should have made a very decided step in the desired direction. I need not say that various attempts have been made to clear up so important a point; but we have to deal with complicated forces, and the attempts have as a rule not been crowned with much success.

There are, however, a few exceptions, a few cases of greater simplicity than the rest, where we are able to trace to their mechanical causes the spectroscopic changes which take place on chemical combination. These few and simple cases may serve as the finger-posts which show us the way to further research, and, we may hope, to further success. To make the spectroscopic changes of which I am speaking clear to you, I must have recourse to the analogy between sound and light, and remind you of the fact that when the prongs of a tuning-fork are weighted its tone is lowered, which means that the

period of vibration is increased, and consequently that the length of the wave of sound sent out is lengthened. Now, suppose a molecule or atom, the spectrum of which I am acquainted with, enters into combination with another; and suppose that the vibrations of the second molecule are weak, or lie outside the visible range of the spectrum: then the most simple assumption which I could make would be that the addition of the new molecule is equivalent to an increase of the mass of the other. An increase of mass without alteration of the force of the molecule will, as in the case of the tuning-fork, lengthen the period of vibration, and increase the wave-length. If a case of that kind were actually to happen, I should observe the whole spectrum shifting toward the red; and this is what is observed in the few simple cases to which I have referred. The first observation to that effect is due to Professor Bunsen, of Heidelberg. Examining the absorption spectra of different didymium salts, he found such a close resemblance between them, that no difference could be detected with instruments of small powers; but with larger instruments it was found that the bands varied slightly in position, that in the chloride they were placed most toward the blue end of the spectrum, that when the sulphate was substituted for the chloride a slight shift toward the less refrangible end took place, and that a greater shift in the same direction occurred on examining the acetate. Prof. Bunsen remarks that the molecular weight of the acetate is larger than that of the sulphate, and that the molecule of the sulphate, again, is heavier than that of the chloride. He adds: "These differences in the absorption spectra of different didymium compounds can not, in our present complete state of ignorance of any general theory for the absorption of light in absorptive media, be connected with

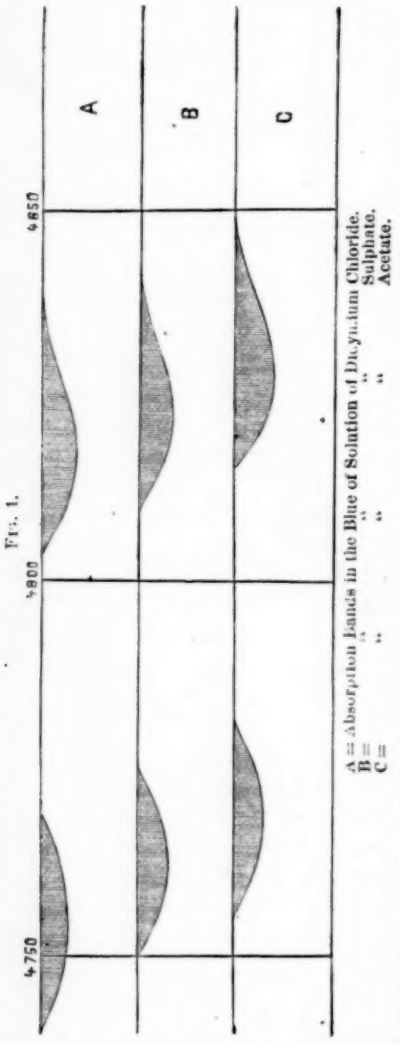
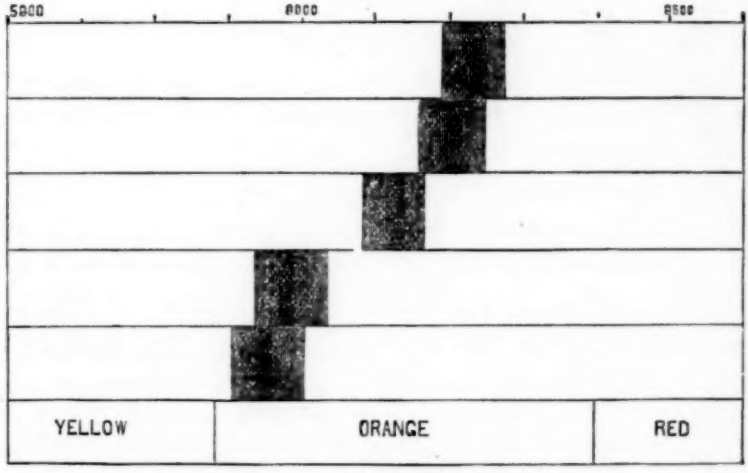


FIG. 1.

other phenomena. They remind one of the slight gradual alterations in pitch which the notes from a vibrating elastic rod undergo when the rod is weighted, or of the change of tone which an organ-pipe exhibits when the tube is lengthened." The accompanying woodcut (Fig. 1), copied from Professor Bunsen's paper, may serve to illustrate the shift observed in one of the absorption bands.

Similar changes take place when some substances like cyanin and chlorophyl are dissolved in different liquids. Absorption bands characteristic of these various substances appear, but they slightly vary in position. Professor Kundt, who has carefully examined this displacement of absorption bands, has come to the conclusion that as a rule the liquids of high dispersive powers were those which shifted the bands most toward the red end of the spectrum. But, though there is an apparent tendency in this direction, no rule can be given which shall be absolutely true whatever the substance which is dissolved. Fig. 2 shows the absorption spectrum of cyanin when dissolved in dif-

FIG. 2.



A = Absorption of Cyanin in Bisulphide of Carbon.
B = " " " Nitrobenzene.
C = " " " Benzene.
D = " " " Ether.
E = " " " Alcohol.

ferent liquids. The measurements made by Claes* are employed. We have here an interesting proof that a solution is sometimes much more of a chemical compound than is generally supposed. The solvent and the substance must, indeed, be closely connected in order to produce a shifting of the absorption band. On the other hand, it is not astonishing that no general law can be given which connects the displacement with the physical properties of the solvent, for the closeness of connection depending on the special chemical affinity for each

* "Wied. Annalen," iii, p. 388, 1878.

solvent has as much to do with the amount of shifting observed as the molecular weight or the dispersion or refractive power may have. The shifting of the absorption bands in different solutions of the same substances is only one of many applications of spectroscopes to the examination of molecular phenomena in liquids. Into the interesting researches of Professor Russell, who has greatly extended this field of inquiry, we have no time to enter.

The changes of spectra due to molecular combinations and rearrangements have in addition to their theoretical importance a great practical interest, for they will afford us some day a means of answering approximately a great many questions relating to the temperature of sun and stars. The gases and vapors in the solar atmosphere are for the greater part in the molecular condition in which they give a line-spectrum, and we know of stars the spectra of which resemble our solar spectrum very nearly. We shall not be far wrong in ascribing to such stars a temperature similar to that of our sun. Other stars have absorbing envelopes showing spectra of fluted bands. We know that fluted bands belong to a more complex molecular condition, which only can exist at lower temperatures. These stars, therefore, must have a lower temperature than our sun. Dr. Huggins, who has succeeded in obtaining most valuable photographs of star-spectra, has been able to classify and arrange star-spectra; and it is more than likely that, in the series of stars arranged in order by means of their spectra, we have at one end those of the highest, at the other those of the lowest, temperature. We are as yet far from being able to assign any particular temperature to a star, but the question by means of the spectroscope has been reduced to one which can be decided in our laboratories, and, however difficult it may be, we may rest assured that it will ultimately be solved. As to our sun, its temperature has been the subject of many investigations. Attempts have been made to deduce it (at least approximately) from the amount of heat it sends out. Different experimental laws have been proposed to connect together the heat radiation of a body, and the temperature of that body. The first law which was thus proposed gives 10,000,000° Centigrade as a lower limit; the second law reduces that lower limit to a little over 1,500°. Both these laws we now know to be wrong. More accurate laws give something like 10,000° or 20,000°, but the whole method employed is one which is open to a great many objections.

We measure the combined heat radiation of different layers on the solar surfaces, all of which are at different temperatures, and we observe only an average effect which is much influenced by the absorption in the outer layers of the solar atmosphere and in the corona, and does not admit of easy interpretation. The spectroscopic method, which is yet in its infancy, has the advantage that we can observe separately each layer of the sun; and we thus examine the temperature not as an average, but for every part of the solar body. Our way

to proceed would consist in carefully observing the spectra in different layers of the sun. Supposing we observe a change at one point, we may investigate at what temperature that change takes place, and we may then ascribe the same temperature to that particular place at the solar surface, if no other cause has interfered which may have affected our result. This last conditional limitation leads us to the discussion of the important but difficult question, whether we can determine any such interfering cause, which, not being temperature, yet produces the same change in a spectrum which we have hitherto only ascribed to changes of temperature.

I must here remark that a change in type is not the only spectroscopic change in the spectrum which is observed to take place on varying the temperature. Line-spectra especially are subject to curious variations in the relative intensities of their lines. These variations follow no general rule, and must be investigated separately for each element. The cause of this variation is a subject on which there exists a great difference of opinion ; but, whatever this cause may be, if the changes always take place at one fixed temperature, we can turn them into account in measuring that temperature. However strong our wish that such a spectroscopic measurement of temperature may ultimately be obtained, a remarkable complication of facts has delayed the realization of this hope for at least a considerable period of time.

We have to enter partly into a theoretical question, and I must necessarily allude to some of the facts recognized by all who believe in the molecular theory of gases. Each molecule, which, as we have seen, sends out rays of light and heat on account of its internal motion, is surrounded by other molecules. These are, indeed, very closely packed, and continually moving about with enormous velocities. Generally they move in straight lines, but it must necessarily happen that often they come very near, and then affect and deflect each other. Perhaps they come into actual contact, perhaps they repel each other so strongly when near, that contact never takes place. The time elapsing between two such collisions is very small. If you can imagine one second of time to be magnified to the length of a hundred years, it would only take about a second, on the average, from the time a molecule has encountered one other molecule until it encounters the second. During the greatest part of this very short time, it moves in a straight line, for the forces between molecules are so small that they do not affect each other unless their distance is exceedingly small. It is, therefore, only during a very small fraction of time that one molecule is under the influence of another, and it is one of the greatest problems of molecular physics to find out what happens during that short element of time. I should like to explain to you how I believe the spectroscope may contribute its share to the settlement of that question. In his first great paper on the molecular theory of gases, the late Professor Clerk Maxwell assumed that two molecules may

actually come into contact, that they may strike each other, as two billiard-balls do, and then separate, according to the laws of elastic bodies. This theory is difficult of application when a molecule contains more than one atom, and, especially as it did not in the case of conduction of heat give results ratified by the experimental test, Maxwell abandoned it in favor of the idea that molecules repel each other according to the inverse fifth power of the distance. This second theory not only gave what at the time was believed to be the correct law for the dependence of the coefficient of conduction on temperature, but it also helped its author over a considerable mathematical difficulty. Further experiments have shaken our faith in the first of these two reasons, and the second is not sufficient to induce us to adopt without further inquiry the new law of action between two molecules.

It is exceedingly likely that the forces acting between two molecules when they are in close proximity to each other are partly due to, or at least modified by, the vibrations of the molecules themselves. Such vibrations must, as in the case of sound, produce attractive and repulsive forces, and vibrating molecules will affect each other in a similar way as two tuning-forks would. Now, if the forces due to vibrations play any important part in a molecular encounter, the spectroscope will, I fancy, give us some information. If two molecules of the same kind encounter, the periods of vibration are the same, and the forces due to vibration will remain the same during, perhaps, the whole encounter. If two dissimilar molecules encounter, the relative phase of the vibrations, and hence the forces, will constantly change. Attraction will rapidly follow repulsion, and the whole average effect will be much smaller than in the case of two atoms of the same kind. We have no clear notion how such differences may act, and we must have recourse to experiment to decide whether any change in the effect of an encounter is observed when a molecule of a different kind is substituted for a molecule having the same periods of vibration.

When a body loses energy by radiation, that energy is restored during an encounter; the way in which this energy is restored will profoundly affect the vibrations of the molecule, and hence the observed spectrum. I have endeavored by means of theoretical considerations, or speculations, as you may perhaps feel inclined to call them, to lead you on to an experimental law which I believe to be of very great importance. The spectrum of a molecule is in fact variable at any given temperature, and changes if the molecule is surrounded by others of different nature.

Placing a molecule in an atmosphere of different nature without change of temperature produces the same effect as would be observed on lowering of temperature.

Let me give you one example. Lithium at the temperature of the Bunsen flame has almost exclusively one red line in its spectrum. At the high temperature of the arc or spark the red line becomes weak,

and almost entirely disappears. It is replaced by a strong orange line, which is already slightly visible, though weak, at low temperatures, and by additional green and blue lines.

But even at the high temperature of the spark we may obtain again a spectrum containing the red line only if we mix a small quantity of lithium with a large quantity of other material. The same spark, for instance, will give us the low-temperature spectrum of lithium when taken from a dilute solution of a lithium salt, and the high-temperature spectrum when that solution is concentrated.

The spectra of zinc and tin furnish us other examples in the same direction, but the spectra of nearly all bodies show the same law in a more or less striking way.

If this law which I have given you is a true one,* and I believe it will stand any test to which no doubt it will be subjected, we shall be able to draw some important conclusions from it. In the first place, it will be proved that the forces between atoms do depend on their vibrations. If this is true, any change in the vibrations of the spectrum, however small, will entail a corresponding change in all the other properties of the body. On the other hand, any change in the affinities of the element observed by other means will be represented by a change in the spectrum.

It is also possible that the introduction of forces due to vibratory motion will help us over a considerable difficulty in the molecular theory of gases. Some of the conclusions of that theory are at present absolutely contrary to fact. A spectroscopist, for instance, who is acquainted with the mercury spectrum and all the changes in that spectrum which can take place, feels more than skeptical when he is told that the molecule of mercury contains only one atom, which neither rotates nor vibrates.

Nor can it be of advantage to science to pass silently over this difficulty, or to neglect it as unessential, as is often done by modern writers. The late Professor Maxwell, at least, was well aware of its importance, and has often expressed in private conversation how serious a check he considered the molecular theory of gases to have received. This is not the place to enter more fully into this point, and to consider how the vibratory forces may affect some of the suppositions on which the theoretical consequences are founded.

However important the effects of concentration or dilution on the

* Lockyer, "Studies in Spectrum Analysis," p. 140, draws attention to the fact that an admixture of a second element dims the spectrum of the first, and he expresses this fact by saying, "In encounters of dissimilar molecules the vibrations of each are damped." Later he has shown that the lines of oxygen and nitrogen, which are wide at atmospheric pressure, thin out when the gases are only present in small quantities. Lecoq de Boisbaudran in his "Atlas" gives several examples of the differences in the relative brilliancy of lines produced by concentrating or diluting the solution from which the spark is taken. The complete parallelism of this change to the changes produced by increased temperature has, however, never received sufficient attention.

spectra may be, they render the spectroscope less trustworthy as a thermometric instrument; for, if the company in which a molecule is placed changes the spectrum in the same way as temperature would, it will be difficult to interpret our results. But, although the discussion of our observations may be rendered more arduous and complicated, we need not on that account despair. It is one of the problems of spectroscopy to find out the composition of bodies, not only qualitatively, but also quantitatively, and, when we shall know in what proportion different bodies are distributed in the sun, we may reduce the problem of finding out this temperature to the much simpler one of finding out the temperature of a given electric spark.

I hope that the few facts which I have been able to bring before you to-night have given you some idea of the important questions which have been brought under the range of spectroscopic research. Many of these questions still await an answer, some have only been brought into the preliminary stage of speculative discussion, but the questions have been raised, and the student of the history of science knows that this is an important step in its development and progress. The spectrum of a molecule is the language which that molecule speaks to us. This language we are endeavoring to understand. The inexperienced in a new tongue which he is trying to learn does not distinguish small differences of intonation or expression. The power over these is only gradually and slowly acquired. So it is in our science. We have passed by, and no doubt still are passing by, unnoticed differences which appear slight and unimportant, but which when properly understood will give us more information than the rough and crude distinctions which have struck us at first. We have extended our methods of research; we have extended our power over the physical agents; we can work with the temperature of sun and stars almost as we can with those in our laboratories. No one can foretell the result, and perhaps in twenty years time another lecturer will speak to you of a spectroscopy still more modern in which some questions will have received their definite answer, and by which new roads will have been opened to a further extension of science.

ORIGIN AND HISTORY OF LIFE INSURANCE.

By THEODORE WEHLE.

LIFE insurance is based upon the theory that there is a law of mortality governing life; that is to say, that at all ages from birth to the utmost limits of life a certain proportion of individuals will die during fixed periods. Not that the precise duration of an individual life can be predicted, but that the ratio of deaths out of large aggre-

gates will remain the same under similar conditions. This conception, so self-evident to-day, was slow to dawn upon the human mind. Ancient pagan belief, various forms of superstition, as well as theology, all assumed life to be under the special control of a mysterious and arbitrary power. The conviction that it is subject to laws, as unalterable as those that govern the physical universe, has only gained ground within a comparatively recent period. Nor could such a view assert itself until mathematics and statistics had reached a certain degree of perfection; for, previous to that, the law of averages and probabilities, as applicable to social problems, could not be understood.

Even after science had taken the initiative, and formulated the law upon such data as were accessible, a long period elapsed before steps were taken to apply its principles to practical ends. The conditions of society were as yet too unsettled, property and life too insecure, to permit such experiments. Not until after the middle of the eighteenth century did the desire to provide for widows, orphans, and other dependents, become so general as to lead to the establishment of a life-insurance society in London.

Since then the system has been steadily perfected, and has grown to considerable dimensions all over the civilized world. At present more than 600,000 lives are insured in the United States alone; and the usefulness of the institution is only beginning to be properly appreciated. In view of this fact, and of the general interest that co-operative enterprises are attracting just now, it may be well to point out that life insurance must be reckoned among the grandest and most successful efforts ever attempted in that direction. It has, moreover, a century's experience to attest the strictly scientific principles upon which it rests. Such an institution well deserves to be better and more generally understood; but, however large the number directly interested, it is strange how few have correct notions about it. This is probably attributable to the character of the literature on the subject, which, addressed to specialists, employs many technical terms, or, intended for soliciting agents, contains mere platitudes. Thus the impression prevails that it is either too dry or veiled in too much mystery to deserve the attention of even the educated classes.

It will be the aim of these articles, while giving an outline of the origin and history of mortality-tables, the results attained, and an explanation of the practical working of the whole system, to present it in so plain and popular a manner as to be readily understood by every intelligent reader.

I. Origin and History.—Among the nations of antiquity, the Romans were the first to make an effort to arrive at a law of mortality. To this they were led indirectly by their highly developed system of jurisprudence. It became necessary at times to fix the value of life-estates, i. e., property owned during lifetime only, without the right of alienation or bequest, and to do so the probability of life had to be

estimated. It appears that the method in common use was about equivalent to assuming that all persons who attain the age of thirty would certainly live to the age of sixty, and then certainly die. This purely arbitrary assumption was probably accepted by jurists as the simple solution of a difficult problem.

A great improvement was introduced by the Prætorian Prefect Ulpianus, one of the most eminent of Roman jurists. He published a table of mortality, in which a distinction was made between the different ages, and the probable number of years of life for each given. The rate of mortality assumed for the middle ages approximates to that probably prevalent previous to the seventeenth century. Whether this table was based upon actual observation or was purely speculative is not settled; but, if its estimates were correct, the chances of life above sixty years were very poor indeed among the Romans. However, these early efforts do not seem to have exercised any influence toward a proper investigation of the subject, and, having been forgotten, they only possess a passing interest for us.

The real germs from which life insurance ultimately developed were life-annuities and tontine annuities. These latter derived their name from a Neapolitan adventurer, Tonti, who came to Paris in 1653, in the reign of Louis XIV. He formed associations based upon the agreement that members should pay a certain sum of money into a fund, which was to be managed by him or other founders. The interest on this capital was annually divided among the surviving members, and, as their number grew smaller, their income became larger from time to time, until eventually the last survivor enjoyed the whole annual proceeds, which often were considerable. An instance is given of a widow who died in France in 1726, at the age of ninety-six, as the last survivor of a tontine society, having an income of 79,000 francs; her husband had been a surgeon, and had paid 300 francs for her membership in the association.

Such schemes were naturally attractive, and spread rapidly over Europe. Various modifications were introduced, adapting them to changing circumstances. Even governments had recourse to them as a means of raising money, when credit was low. The English Government made a tontine loan in 1693, comprising 1,002 members, the last of whom died in 1783. The other, known as the Great English Tontine, was started in 1789 for £1,000,000, embracing about 3,500 lives.

Voluntary associations for specific purposes were also quite frequent. One of a later date, originating in this city, may be mentioned by way of illustration. The Tontine Association of New York, established in 1794 by prominent merchants, upon 203 shares, applied its fund of about $40,000 to the erection of a coffee-house at the corner of Wall and Water Streets. There was an agreement that, when the nominees (mostly young children of the originators) should be reduced

to seven, the association should come to an end. Accordingly, in 1870, the requisite number being reached, steps were taken to have the property (which was then valued at $200,000) divided.

The advantages the tontines seemed to offer made them very enticing. The larger the number of deaths a prospectus would promise, the greater the expected gain to the survivors. No reliable calculation or precise prediction of the mortality was necessary, since they were to be guided by the actual experience only. But the very ease with which they could be formed tended to make them deteriorate into little better than mere lottery schemes, used by designing men to plunder the credulous.*

At present the tontine principle does not enlist our sympathy, being too selfish for our times, but it probably answered a good purpose in its day. Life and property were insecure, the investment of small sums difficult, the usury laws stringent: how natural for men to look to immediate enjoyment, when provision for the future was surrounded by so many uncertainties!

Nor is it likely that Tonti was the real originator of the idea. There is reason to assume that similar customs had taken root in Italian cities long before his time. Probably the same conditions and needs of society also led to the practice of purchasing life-annuities. It seems to have been a favorite mode of raising money, among the flourishing towns of the Netherlands, since the early part of the sixteenth century. On the payment of a certain sum to the party granting the life-annuity, a fixed annual income could be secured during lifetime.

Two other methods of making loans were also known to these old communities, namely, terminable and perpetual annuities.

Terminable annuities are such as are redeemable after a fixed number of years, and bear interest until maturity. That is the usual mode of investing funds at present.

Perpetual annuities are those that bear interest for ever, while the principal never becomes payable. Many European governments have funded their debts upon that principle, the most noted being the French *rentes* and the English consols.

The people of the Netherlands, that so early displayed commercial and political activity, continued to grow in importance until, by the middle of the seventeenth century, they ranked among the foremost nations of Europe. The freedom they enjoyed fostered material prosperity and encouraged the arts and sciences. Their statesmen and officials were often men of the highest attainments.

* These tontine associations must not be confounded with the so-called tontine life-insurance policies issued by some companies at the present day. These latter have simply borrowed the name, while in other respects they are like ordinary life-insurance policies; only that, instead of having dividends declared annually, they are held back for fixed periods, say ten or fifteen years, and then distributed among the surviving members.

One of the greatest among these was Jan de Witt, Grand Pensionary of Holland and West Friesland, a disciple of Descartes, and author of a mathematical work of note.

About contemporary with him, the eminent French thinker, Pascal, had laid down the first principles of the doctrine of chances. The celebrated Christian Huygens enlarged upon these inquiries in a treatise written in Dutch. When, in 1671, the States-General applied to De Witt to elaborate the best plan for raising a loan, he was the first to apply the principles of the science to a practical subject. In a memorable report he states that, for reasons given, it is better to negotiate funds by life-annuities, which by their nature are terminable, than to resort to either perpetual or terminable annuities. He shows that it had long been the practice in Holland to grant life-annuities at double the rate of interest current. That is to say, if four per cent. was customary, a loan of one hundred florins would bring four florins per annum, while one hundred florins applied to the purchase of a life-annuity would yield an income of eight florins. He goes on to prove that the practice of making no distinction between the ages, the selling a life-annuity on the same terms to the young and the old, was based on a fallacy. He then applies the doctrine of chances to data, most likely deduced from former annuity experiences, and proceeds to construct a mortality-table. This table, though erroneous in many respects, is still the first application of mathematical principles to questions of this kind, and, as such, deserves the highest consideration.

The report was never acted upon, and was lost before De Witt's contemporaries had become acquainted with it.

Toward the end of the seventeenth century, the subject of calculating a table of mortality began to create interest in scientific circles in England; but the difficulty was, to obtain reliable statistics. A few registers had been kept since 1538, and by 1600 they had been introduced into probably one half the parishes of England. Unfortunately, only births or baptisms had been entered. During the plague, the government was induced to publish mortality bills, showing the number of deaths; but here, also, the ages were not stated. The Royal Society, finding no data at home, turned to the Continent of Europe.

The city of Breslau, in Silesia, had kept an exact register of births and deaths for some time, and reliable copies for the five years from 1687 to 1691 were obtained. These were intrusted to the Astronomer Royal, the celebrated Dr. Halley, renowned for having calculated the orbit of a comet, which has been named after him. He published a treatise, which appeared in the "Philosophical Transactions" in 1693, giving the following mortality-table, the first that had ever been constructed on exact scientific principles:

BRESLAU TABLE.

Age.	Living.	Age.	Living.	Age.	Living.	Age.	Living.	Age.	Living.
1	1,000	19	604	37	472	55	292	73	109
2	855	20	598	38	463	56	282	74	98
3	789	21	592	39	454	57	272	75	88
4	760	22	586	40	445	58	262	76	78
5	732	23	579	41	436	59	252	77	68
6	710	24	573	42	427	60	242	78	58
7	692	25	567	43	417	61	232	79	49
8	680	26	560	44	407	62	222	80	41
9	670	27	553	45	397	63	212	81	34
10	661	28	546	46	387	64	202	82	28
11	653	29	539	47	377	65	192	83	23
12	646	30	531	48	367	66	182	84	20
13	640	31	523	49	357	67	172	85	15
14	634	32	515	50	346	68	162	86	11
15	628	33	507	51	335	69	152	87	8
16	622	34	499	52	324	70	142	88	5
17	616	35	490	53	313	71	131	89	3
18	610	36	481	54	302	72	120	90	1

Considering the disadvantages under which he labored, it was a wonderful production. He had no record of the whole population, and only 6,193 births and 5,869 deaths of all ages from which to draw his deductions.

The form of the table has been substantially retained to the present day. It begins with 1,000 children, in the first year of life, of whom 145 die in the course of the year. At the beginning of the second year there are 855 living, of whom 66 die in the course of that year; and so the table continues until, at the age of 90, the last one of the original number will die. The probability of dying in any one year of life is readily ascertained. For instance, in the first year of life, 145 die out of 1,000. Therefore, the probability of dying is $\frac{145}{1000} = \cdot 145$. In the second year 66 die out of 855, which makes the probability $\frac{66}{855} = \cdot 077$. That is to say, according to Halley's table, 14½ per cent. of all newly-born children will die in the first year of life, and about 7¾ per cent. in the second year. Another interesting deduction pointed out by him is what a modern actuary has called the equation of life. It will be observed that, out of 1,000 at age 1, 499 will survive at 34, which indicates that the chances of dying or living to age 34 are about equal for a child at birth. It may be applied to any other age. At 19 the table shows 604 living, while at 54 there are 302; therefore, a youth at 19 has, to age 54, an equal chance of living or dying.

Whether Halley's table is a correct exposition of the mortality of the time it is difficult to say, since his data may have been insufficient; but the reasoning on which it was based and the conclusions drawn were strictly scientific.

But, while Halley's treatise must have been highly appreciated by mathematicians, the public at large seemed to have remained ignorant

of its value. Life-annuities continued to be sold on mere conjecture. Even the English Government made no distinction between different ages in the early part of the eighteenth century. A child at ten years could obtain a life annuity of £100 for £714, while it was probably worth over £1,300 at that time.

It is not within the province of this article to trace in detail the progress made in the science of life contingencies. Nearly every mathematician of note contributed to the perfection of the theory, while it was left almost exclusively to England to apply it in practice.

Passing over minor writers, Thomas Simpson, a self-taught mathematician, a mind of great originality, next deserves notice. In 1742 he enlarged upon the theory of Halley, De Moivre, and others, and, deeming the Breslau table not applicable to English conditions, he compiled and computed a mortality-table from the London mortality bills from 1728 to 1737. For a number of years he published pamphlets and delivered lectures on the subject, attracting the attention of the public at large.

Shortly thereafter James Dodson, also a very able mathematician, employed Simpson's tables, and made many valuable additions and suggestions thereto. He contributed a number of able papers to the "Philosophical Transactions," and was the first to point out, in 1755, how mortality-tables might be applied to the calculation of life-insurance premiums.

Up to this time, it will be noticed, life insurance in the modern sense was unknown. Both tontines and annuities had the very opposite object in view, sacrificing the whole capital for an increased income during lifetime. The reasons that made tontines popular have been briefly touched upon. Similar causes applied to life-annuities; besides, they provided a convenient way of evading the usury laws, and were often resorted to for that purpose. It was impossible to discriminate what part of the high rate of interest paid was for the use of money, and what percentage was due to the chance of death.

But, while life insurance as a system is of recent date, the practice of effecting temporary insurance on lives had its origin with the rise of marine insurance, probably as early as the fourteenth century. It was no more, however, than a mere bet, not based upon any experience or estimate, and led to many immoral devices. On that ground it was declared unlawful, and prohibited in the Netherlands, Spain, and Italy, together with other wager contracts, as far back as the fourteenth and fifteenth centuries. In England, however, there was no restriction, and, in the eighteenth century, betting on the lives of prominent men was carried on regularly at Lloyd's and other coffee-houses in London.

The spirit of gambling, that set in with the South-Sea bubble in 1720, continued to ebb and flow until the statute against wager contracts was enacted in 1773. It gave rise to a large number of wild

insurance schemes, most of which were ridiculous, while many were intentional frauds. The failures that necessarily followed created distrust and retarded the efforts that were just beginning to be made to introduce legitimate life insurance.

But a new era had begun in the history of the English people. The cessation of internal strife, the settlement of fundamental, constitutional questions, the increase of material prosperity, the greater power and intelligence of the people, and the growth of large towns, particularly London, had completely changed the conditions of society as compared with previous centuries. Selfishness and brutality gradually yielded to more forethought and refined feeling; family ties grew warmer and more generous. Comforts were greater, life and property more secure, and everything tended to a more vivid desire in thoughtful men to provide for their families in the contingency of their own death. The feeling was most pronounced among the clergy and other professional classes, and associations began to form to accomplish that purpose. The conditions on which they were based were somewhat similar to those even now in vogue, with benevolent institutions having the same object in view. On the death of a member, his heirs would receive a certain contribution from the surviving members.

Such arrangements, when a mere subordinate feature of benevolent societies, may work well for a time, but they can not serve as substitutes for life-insurance companies. These can only be founded on scientific principles, and all other devices must be futile and short-lived, as a century's experience has amply shown. The difficulties to be encountered were clearly foreseen and explained by the mathematicians of the day, and their labors did not prove in vain. In 1761 a number of gentlemen petitioned Parliament for a charter for a life-insurance association. They met with opposition, on the ground that the undertaking was purely speculative, devoid of any merit, and sure to fail. The charter not being granted, they organized in 1765, as a mutual insurance company, under the title of "The Equitable Society."

They were the first to issue policies for life, for a fixed amount, and at premiums not merely conjectural. Still, for a number of years their progress was very slow. But the public mind was agitated on the subject, and many men of superior ability were absorbed by it. Most prominent among these was Dr. Price, an unsuccessful Unitarian preacher, who had contributed many excellent papers to the "Philosophical Transactions," and published treatises on annuity values. He was consulted by one of the many insurance societies then forming, all of which he found started on a basis sure to lead to ruin. As he expressed it, "All London seems to be entering societies of this sort," and he determined to examine the subject thoroughly. What appeared an easy task proved the arduous labor of many years. The London mortality bills could not serve as a proper basis for insurance

calculations. The large and fluctuating population of a city like London, with its extremes of social conditions, could not be deemed a fair exponent of the value of healthy lives of the whole country. Dr. Price set to work to collect data from which trustworthy tables might be computed. He constructed quite a number of them, among which, one based on thirty years' mortality of Norwich, and another on ten years' observation at Chester, attracted considerable notice. He also applied such French, Dutch, and Swedish statistics as were available. But most important of all, and the one on which his fame chiefly rests, was the Northampton table, taken from thirty years' mortality observations of the town of Northampton. At the time of its publication, Dr. Price's numerous works had become widely known and his reputation was well established. In 1780 the Equitable Society, which had commenced with Dodson's London tables, concluded to adopt the Northampton table, and Dr. Price became the Society's consulting actuary. The directors generally followed his suggestions, and within a year he made 20,000 computations for them. The Society, now basing the reserves on the Northampton table, which showed a lower rate of mortality than Dodson's, found the surplus to accumulate rapidly, and large and frequent dividend additions were made to the old policies. With the reduction of the premiums the business increased steadily, and numbers of new companies were started in competition, whose fate we need not follow. Life insurance had become a practical system, established on a scientific basis.

The directors of the Equitable Society were intelligent and enterprising but very careful men. They had selected the Northampton table, from the different new tables presented, because among these it showed the highest rate of mortality. It proved to be based on a peculiar error of reasoning. An enumeration of the whole population could not be obtained, and the parish registers only gave a record of the christenings and deaths. But the town contained great numbers of Baptists, who repudiate infant baptism; and Dr. Price overlooked the fact that births and christenings were not identical, and assumed a much higher proportion of deaths to births than had actually occurred. The Northampton table came into general use, however, and the English Government, that had adopted it as a basis for annuity values, lost about £2,000,000 before its inaccuracy was discovered.

The next step of importance was the publication of a new mortality table, known as the Carlisle table, by an eminent actuary, Mr. Joshua Milne, in 1816. It was deduced from data obtained from the town of Carlisle, a very healthy and prosperous place, growing both by immigration and natural increase. During the eight years from 1779 to 1787 the population had risen from 7,677 to 8,677 inhabitants, being just 1,000, and the deaths recorded were 1,840. While the number under observation was very small, the advantage of having enumerations of the whole population was considerable. For the first

time it was possible, not only to compare births and deaths, but also to determine their proportion to the living. With the exception of the very young and old ages, where the numbers had been too few to make it reliable, the excellence of the Carlisle table was so pronounced that it quickly superseded the Northampton table, and remained in use until within a very recent period. With its adoption, premiums were again lowered, and the business increased largely. It outgrew the experimental stage, and, until then confined to England, began to extend to the Continent of Europe.

THE INSUFFICIENT USE OF MILK.

By DYCE DUCKWORTH, M. D., F. R. C. P.

I DESIRE to call attention to the insufficient employment of milk as an ordinary article of diet in this country. It may seem hardly possible to maintain that such a complaint is rightly grounded. All classes of persons are supposed to use milk, to some amount, as a matter of course. And although adults are not supposed to take very much, save what they consume with tea and coffee, yet children are commonly credited with the consumption of a good deal, or, at all events, of a sufficiency, of this commodity.

In this communication I propose to show that this common belief is largely erroneous, and that persons of all classes, and of all ages, in England, consume too little milk. The consequences of this starvation I hold to be serious, and the remedy for it perhaps not far to seek. The subject may be best considered, first, as it affects the communities settled in cities and towns ; and, secondly, in relation to the peasantry and country population generally.

Is is not too much to say that a fitting supply of milk is at present too seldom secured even by families who can well afford to pay for it. The full value of milk as an article of diet is not yet sufficiently appreciated by people who ought to be aware of it. Many adults regard it mainly as food for children, and many believe that they can not digest it, and state that it "curdles on the stomach," and makes them "bilious." The ordinary milk-supply to many establishments is just sufficient to allow their tea and coffee to be colored with it. A very inadequate quantity is often given to children, and the quality of it is no better than that yielded by skimmed milk, with, possibly, more or less water added to it. And in such households as I am now referring to, there is often, curiously enough, a stinginess in respect to cream, or what is made to pass for it, which, paltry and niggardly as it is, contrasts ridiculously, and I will say vulgarly, with the more free expenditure not uncommonly assented to on bad sherry and worse claret.

Any one, who knows what is meant by a cup of good tea, knows also that a certain quantity of good cream is an essential ingredient in it. There is, then, an incongruity between the inadequate supply of milk and cream and the free use of wine in such households, and the consequence is a serious nutritional loss to all the members of it.

The question of expense, however, does come to be a consideration in many families who are consistently economical, yet, even here, I maintain that a false economy prevails, if milk be in any degree stinted to their young and growing members.

The poorer classes are greatly starved of milk in the towns. Many among them so seldom get good milk that they acquire gradually a complete distaste for what goes by the name. The same, too, is the case with tea and coffee. The miserable decoctions which, among the poor, pass for these precious beverages, are so far from what they might and should be, that these people are naturally led to the unwholesome substitutions of bad beer and worse gin. A cup of good tea or coffee, with abundant milk in it, is a very unwonted treat and novel experience to the poor. I find much difficulty in enjoining the use of milk among hospital out-patients (and I order nothing so freely), partly, because they are incredulous as to its value ; partly, because they can not get enough of it, and when obtained it is so inferior ; and also, because they either dislike it, or allege that it disagrees with them. A sickly laborer, for instance, accustomed to sundry pints of beer and "drops" of gin, is aghast at the recommendation to substitute for these a pint or two of milk. Milk is as nauseous for him as his physic, possibly more so.

Now, in the matter of taking milk, there are reasons why this repugnance is felt. We most of us take, and enjoy, that which we have been accustomed to get, and those who have been brought up largely on milk naturally regard it with liking. Thus, the hardy Scotsman or Irishman, who has been well nourished on buttermilk, can well appreciate good milk when it is forthcoming. The southern Englishman is a poor creature in this respect.

Again, milk is a food that should not be taken in copious draughts like beer, or other fluids, which differ from it chemically. If we consider the use of milk in infancy, the physiological ingestion, that is, of it, we find that the sucking babe imbibes little by little the natural food provided for it. Each small mouthful is secured by effort, and slowly presented to the gastric mucous surface for the primal digestive stages. It is thus regularly and gradually reduced to curd, and the stomach is not oppressed with a lump of half-coagulated milk. The same principle should be regarded in the case of the adult. Milk should be slowly taken in mouthfuls, at short intervals, and thus it is rightly dealt with by the gastric juice. If milk be taken after other food, it is almost sure to burden the stomach, and to cause discomfort and prolonged indigestion, and this, for the obvious reason that there

is insufficient digestive agency to dispose of it. And, the better the quality of the milk, the more severe the discomfort will be under these conditions.*

Milk is insufficiently used in making simple puddings of such farinaceous foods as rice, tapioca, and sago. Distaste for these is engendered very often, I believe, because the milk is stinted in making them, or poor, skimmed milk is used. Abundance of new milk should be employed, and more milk, or cream, should be added when they are taken. In Scottish households this matter is well understood, and a distinct pudding-plate, like a small soup-plate, is used for this course. The dry messes commonly served as milky puddings in England are exactly fitted to create disgust for what should be a most excellent and delicious part of a wholesome dinner for both children and adults.

I am of opinion that much mischief results from the use of condensed milk, called Swiss milk, for children. I think it has a poor nutritive value compared with fresh good milk, and it is simply foolish for people to employ it when they can procure the real article. At sea, or when such milk as can be had is of doubtful quality, there may be just cause for resorting to it, but it is as unwise to employ it when fresh milk is procurable as it is to use extract of beef when freshly-made beef-tea can be had. I am aware that some infants will only take condensed milk, and appear to thrive upon it, but I think it is not to be trusted to for the highest nutritional purposes, and it should be discarded as soon as possible. The value of milk for the aged is not appreciated as it should be. If old age is a second childhood, the food for such persons should be that adapted to feeble digestive powers and the edentulous condition.

Many invalids and feeble persons can be induced to take milk with rum in it. This is at times a valuable prescription, but I find that people resort to it without medical advice, and some make it practically a mere excuse for a pernicious form of dram-drinking.

Milk and eggs in the form of custard is of high value. Some invalids, it should be known, can take custard-pudding cold when they can not take it hot, and with salt in it instead of sugar.

To illustrate what should be considered a proper milk-supply for a family and household consisting of ten persons, adults and children, I may state that five quarts *per diem* is the least quantity that should be consumed for all purposes. Children of any age may very well take a quart a day. If this, or anything approaching this, were the rule, instead of the exception, rickets, in its manifold phases, would be completely banished from this country, and a much higher standard of health and robustness would unquestionably prevail.

* The addition of a little carbonate of soda or of lime-water will often enable milk to be better digested. It is sometimes well to eat a dry biscuit and sip the milk between the mouthfuls. For weakly children with whom milk disagrees, good cream, diluted with two or three parts of water, may be often substituted with advantage.

I pass, secondly, to consider the present inadequate supply of milk to the peasantry and country people generally. It is not commonly known that the English peasantry get, as a rule, and in many parts of the country, less milk than the population of the towns. The swine are really better off in many instances.

Buttermilk should be used, and proves most wholesome and nutritious. When the gentry in any neighborhood are supplied with milk, little remains for the poorer folks to buy, and much of what they get is either doled out, as a form of charity, from the dairies of the rich, and is already skimmed, or too little for their real wants and requirements remains available for purchase.

The results of this milk-starvation in the country are readily observed; the children suffer much from want of good milk, and, hardly less, many of the adults. Milk and meat are rare commodities among the peasantry who are not so situated as to secure supplies on the estates of their masters. The loss of meat can be far better borne than that of milk. A good supply of vegetables, with cheese and onions, will make up for loss of much animal food, especially if wholesome brown, or whole meal, bread be eaten. The fact that the best bread, as it is termed, is so largely used by the poor, has often been shown to be due to the erroneous belief that the whitest bread is more wholesome and "goes further" than that made from "seconds" flour. A diet of this "best" bread and a scanty allowance of skimmed milk is, in truth, a very poor and ill-nourishing one. The strange fact remains that pampered servants, and the lower orders generally, prefer this poor stuff because it is called the best, while their betters, who eat darker-colored, or whole-meal bread, have no influence whatever in setting them a better example. It must strike all trained observers that there is a great deal of anæmia among the poorer country-folks, even in the healthiest districts, and much of this I believe to be due to errors in diet, and some of it to insufficient use of milk.

It comes to this, therefore—a large increase in our milk-supply is absolutely called for. It seems certain that our farmers can no longer grow cereals so as to make them a source of profit, or to meet the wants of our population. America, Canada, and India can always meet our deficiencies. Our corn-fields are rapidly being laid down in permanent pasture, but the herds of grazing-cattle we were wont to see are gradually dwindling away. Cattle-plague and various murrains explain this lamentable fact. But are these henceforth to prevail to such an extent as to curtail our home-growth of beef and our milk production? I, for one, sincerely trust not, and I hope I am not too sanguine when I express the belief that the time is not far distant when, by a large, a very large, increase in our grazing-stocks, we may at least meet the crying want of a much better milk-supply for the whole country.—*The Practitioner.*

INTELLIGENCE OF ANTS.

By GEORGE J. ROMANES.

I HAVE frequently been much struck by the absence of information, even among professed naturalists and professed psychologists, concerning the intelligence of ants. The literature on the subject being scattered and diffused, it is not many persons who have either the leisure or the inclination to search it out for themselves. Most of us, therefore, either rest in a general hazy belief that ants are wonderfully intelligent animals, without knowing exactly in what ways and degrees the intelligent action of these animals is displayed; or else, having read Sir John Lubbock's investigations, we come to the general conclusion that ants are not really such very intelligent animals, after all, but, as was to have been expected from their small size and low position in the zoölogical scale, it only required some such methodical course of scientific investigation to show that previous ideas upon the subject were exaggerated, and that, when properly tested, ants are found to be rather stupid than otherwise. I have therefore thought it well to write a paper for this widely circulated review, in order to diffuse some precise information concerning the facts of this interesting branch of natural history.

Not having any observations of my own to communicate, I have no special right to be heard on this subject; but, as I have recently had occasion to read through the literature connected with it, I am able to render what I may call a filtered abstract of all the facts which have hitherto been observed by others. It is needful, however, to add that the filter has been necessarily a close one; if I had a large volume instead of a short paper as my containing vessel, the filtrate would still require to be a strongly condensed substance.

Powers of Special Sense.—Let us take first the sense of sight. Sir John Lubbock made a number of experiments on the influence of light colored by passing through various tints of stained glass, with the following results: 1. The ants which he observed greatly disliked the presence of light within their nests, "hurrying about in search of the darkest corners" when light was admitted. 2. Some colors were much more distasteful to them than others; for while under a slip of red glass there were on one occasion congregated 890 ants, under a green slip there were 544, under a yellow 495, and under a violet only 5. 3. The rays thus act on these ants in a graduated series, which corresponds with the order of their influence on a photographic plate. Experiments were therefore made to test the effect of the rays on either side of the visible spectrum, but with negative results. In considering these experiments, however, it is important to remember that other observers (especially Moggridge in Europe, and McCook in America) have

described other species of ants (genus *Atta*) as fond of light. It would be interesting for any one who has an opportunity to try whether ants of this genus do not show toward the rays of the spectrum a scale of preference the reverse of that which Sir John Lubbock described.

As regards hearing, Sir John found that sounds of various kinds do not produce any effect upon the insects, nor could he obtain any evidence of their emitting sounds, either audible or inaudible to human ears.

It has long been known that the sense of smell in ants is highly developed, and it appears to be the sense on which, like dogs, they mainly rely. Huber proved that they track one another's footsteps in finding their way to food, etc.; for he observed, on drawing his finger across the trail so as to obliterate the scent, that the ants became confused and ran about in various directions, till they again came upon the trail on the other side of the interrupted space. By many ingeniously devised experiments Lubbock has amply confirmed Huber's statements, and concludes that in finding treasure "they are guided in some cases by sight, while in others they track one another by scent"—depending, however, more upon scent than upon sight.

There can be little doubt that ants have a sense of taste, as they are so well able to distinguish sugary substances; and it is unquestionable that in their antennæ they possess highly elaborated organs of touch.

Sense of Direction.—It is certain that ants, in common with many other animals, possess some unaccountable sense of direction, whereby they are able to find their way independently of landmarks, etc. Sir John Lubbock tried a number of experiments in this connection, of which the following is perhaps the most conclusive: Between the nest and the food he placed a hat-box, in each of two opposite sides of which he bored a small hole, so that the ants, in passing from the nest to the food and back again, had to go in at one hole and out at the other. The box was fixed upon a pivot, where it could be easily rotated, and, when the ants had well learned their way to the food through the box, the latter was turned half round as soon as an ant had entered it; "but in every case the ant turned too, thus retaining her direction."

Sir John then placed in the stead of a hat-box a disk of white paper. When an ant was on the disk making toward the food, he gently drew the paper to the other side of the food, so that the ant was conveyed by the moving surface in the same direction as that in which she was going, but *beyond* the point to which she intended to go. Under these circumstances the ant did not turn round, but went on to the farther edge of the disk, "when she seemed a good deal surprised at finding where she was."

These results seem to indicate that the sense of direction is due to a process of registering all the changes of direction which may be

made during the out-going journey, and that this power of registration has reference only to *lateral* movements; it has no reference to variations in the *velocity* of advance along the line in which the animal is progressing.

Powers of Communication.—Huber, Forel, Kirby and Spence, Dujardin, Burmeister, Franklin, and other observers have all expressed themselves as holding the opinion that ants are able to communicate information to one another by some system of language or signs. The facts, however, on which the opinion of these earlier observers rested, have not been stated with that degree of caution and detail which the acceptance of their opinion would require. But the more recent observations of Bates, Belt, Moggridge, Hague, Lincecum, McCook, and Lubbock, leave no doubt upon the subject. Two or three instances will be enough to select in order to prove the general fact. Hague, the geologist, kept upon his mantel-shelf a vase of flowers, and he noticed a file of small red ants on the wall above the shelf passing upward and downward between the latter and a small hole near the ceiling. The ants, whose object was to get at the flowers, were at first few; but they increased in number during several successive days, until an unbroken succession was formed all the way down the wall. To get rid of the ants, Hague then tried frequently brushing them off the wall upon the floor in great numbers; but the only result was that another train was formed to the flowers ascending from the floor. He, therefore, took more severe measures, and struck the end of his finger lightly upon the descending train near the flower-vase, so killing some and disabling others. "The effect of this was immediate and unexpected. As soon as those ants which were approaching arrived near to where their fellows lay dead and suffering, they turned and fled with all possible haste, and in half an hour the wall above the mantel-shelf was cleared of ants." The stream from below continued to ascend for an hour or two, the ants advancing "hesitatingly just to the edge of the shelf, when, extending their antennæ and stretching their necks, they seemed to peep cautiously over the edge until beholding their suffering companions, when they too turned, expressing by their behavior great excitement and terror." Both columns of ants thus entirely disappeared. For several days there was a complete absence of ants: then a few began to reappear; "but, instead of visiting the vase which had been the scene of the disaster, they avoided it altogether," and made for another vessel containing flowers at the other end of the shelf. Hague here repeated the same experiment, with exactly the same result. After this for several days no ants reappeared; and during the next three months it was only when fresh and particularly fragrant flowers were put into the vases that a few of the more daring ants ventured to straggle toward them. Hague concludes his letter to Mr. Darwin, in which these observations are contained, by saying:

To turn back these stragglers and keep them out of sight for a number of days, sometimes for a fortnight, it is sufficient to kill one or two ants on the trail. . . . The moment the spot is reached an ant turns abruptly and makes for home, and in a little while there is not an ant visible on the wall.

Many other cases might be quoted to show that ants are able to communicate information to one another; but, to save space, I shall pass on to Sir John Lubbock's direct experiments upon this subject. Three similar and parallel tapes were stretched from an ant's nest to three similar glass vessels. In one of the latter Sir John placed several hundred larvæ, in another only two or three larvæ, and the third he left empty. The object of the empty glass was to see whether any ants might not run along the tapes without any special reference to the obtaining of larvæ; and this was found not to be the case. Sir John then put an ant to each of the other two glasses; they each took a larva, carried it to the nest, returned for another, and so on. Each time a larva was taken out of the glass containing only two or three, Sir John replaced it with another, so that the supply should not become exhausted. Lastly, every ant (except the two which had first been put to the larvæ), before reaching home with her burden, was caught and imprisoned till the observation terminated.

The result was, that during forty-seven and a half hours the ants which had access to the glass containing numerous larvæ brought 257 friends to their assistance; while during an interval of five and a half hours longer those which visited the glass with only two or three larvæ brought only 82 friends. This result appears very conclusive as proving some power of definite communication, not only as to where food is to be found, but also as to the road which leads to the *largest store*. Further experiments, however, proved that these ants are not able to *describe the precise locality* where treasure is to be found. For, having exposed larvæ as before and placed an ant upon them, he watched every time that she came out of the nest with friends to assist her; but, instead of allowing her to pilot the way, he took her up and carried her to the larvæ, allowing her to return with a larva upon her own feet. Under these circumstances the friends, although evidently coming out with the intention of finding some treasure, were never able to find it, but wandered about in various directions for a while, and then returned to the nest. Thus, during two hours, she brought out altogether in her successive journeys no less than 120 ants, of which number only five in their unguided wanderings happened by chance to find the sought-for treasure.

Memory.—The general fact that, whenever an ant finds her way to a store of food or larvæ, she will return to it again and again in a more or less direct line from her nest, constitutes ample proof that the ant remembers her way to the store of food. It is of interest to note that the nature of this insect-memory appears to be identical with that of memory in general. Thus, a new fact becomes *impressed* upon ant-

memory by repetition, and the impression is liable to become effaced by lapse of time. Sir John Lubbock found it necessary to *teach* the insects, by a repetition of several lessons, their way to treasure, if that way were long or unusual. With regard to the *duration* of memory in ants, it does not appear that any direct experiments have been made; but the following observation by Mr. Belt on its apparent duration in the leaf-cutting ant may be here stated: In June, 1859, he found his garden invaded by these ants, and on following up their paths he found their nest about a hundred yards distant. He poured down their burrows a pint of diluted carbolic acid. The marauding parties were at once drawn off from the garden to meet the danger at home, while in the burrows themselves the greatest confusion prevailed. Next day he found the ants busily engaged in bringing up the ant-food from the old burrows and carrying it to newly formed ones a few yards distant. These, however, turned out to be intended only as temporary repositories; for in a few days both old and new burrows were entirely deserted, so that he supposed all the ants to have died. Subsequently, however, he found that they had migrated to a new site, about two hundred yards from the old one, and there established themselves in a new nest. Twelve months later the ants again invaded his garden, and again he treated them to a strong dose of carbolic acid. The ants, as on the previous occasion, were at once withdrawn from his garden, and two days afterward he found "all the survivors at work on one track that led directly to the old nest of the year before, where they were busily employed in making new excavations. . . . It was a wholesale and entire migration." Mr. Belt adds, "I do not doubt that some of the leading minds in this formicarium recollected the nest of the year before, and directed the migration to it." Of course, it is possible that the leaders of the migration may have simply stumbled on the old burrows by accident, and, finding them already prepared as a nest, forthwith proceeded to transfer the food and larvæ; but, as the old and the new burrows were separated from one another by so considerable a distance, this supposition does not seem probable, and the only other one open is that the ants remembered their former home for a period of twelve months. This supposition is rendered the more probable from a somewhat analogous case recorded by Karl Vogt in his "Lectures on Useful and Harmless Animals." For several successive years ants from a certain nest used to go through certain inhabited streets to a chemist's shop six hundred metres distant, in order to obtain access to a vessel filled with sirup. As it can not be supposed that this vessel was found in successive working seasons by as many successive accidents, it can only be concluded that the ants remembered the sirup-store from season to season.

Recognition.—I shall now pass on to consider a class of highly remarkable facts. It has been known since the observations of Huber

that all the ants of the same community recognize one another as friends, while an ant introduced from another nest, even though it be an ant of the same species, is known at once to be a foreigner, and is usually maltreated or put to death. Huber found that, when he removed an ant from a nest and kept it away from its companions for a period of four months, it was still recognized as a friend, and caressed by its previous fellow-citizens after the manner in which ants show friendship, viz., by stroking antennæ. Sir John Lubbock, after repeating and fully confirming these observations, extended them as follows:

He first tried prolonging the period of separation beyond four months, and found that it might be made more than three times as long without the ants forgetting their absent friend. Thinking that this fact could only be explained, either by all the ants knowing each other's personal appearance, or by their all having a distinctive smell peculiar to each nest, or by their all having a sign, like a pass-word, differing in different nests, Sir John tried separating some ants from a nest while still in the condition of larvæ, and, when they emerged as perfect insects, transferring them back to the nest from which they had been taken as larvæ. Of course, in this case the ants in the nest could never have *seen* those which had been removed, for a larval ant is as unlike the mature insect as a caterpillar is unlike a butterfly; neither can it be supposed that the larvæ, thus kept away from the nest, should retain, when hatched out as perfect insects, any smell belonging to their parent nest; nor, lastly, is it reasonable to imagine that the animals, while still in the condition of larval grubs, can have been taught any gesture or sign used as a pass-word by the matured animals. Yet, although all these possible hypotheses seem to be thus fully excluded by the conditions of the experiment, the result showed unequivocally that the ants all recognized their transformed larvæ as native-born members of their community.

Next, therefore, Sir John Lubbock tried dividing a nest into two parts before the queen ants had become pregnant. Seven months after the division the queens laid their eggs, and five months later these eggs had developed into perfect insects. He then transferred some of these young ants from the division of the nest in which they had been born to the division in which they had never been, even in the state of the egg. Yet these ants also were received as friends, in marked contrast to the reception accorded to ants from any other nest. It therefore seems to be blood-relationship that ants are able, in some way that is as yet wholly inexplicable, to recognize. It ought, however, to be remembered in this connection that, in an experiment made by Forel on slave-making ants, it was proved that they almost instantaneously recognized their own slaves from other slaves of the same species—and this after their slaves had been kept away from the nest for a period of four months.

Under this heading I may also allude to the unquestionable evidence concerning enormous multitudes, or, as we might say, a whole nation of ants, all recognizing one another as belonging to the same nationality. No doubt the principle (whatever it may be) on which the power of recognition depends is the same here as it is in the case of a single nest; but, in the cases which I am about to quote, the operation of this principle is indefinitely and incalculably extended. The cases to which I allude are those in which new ants' nests spring up as off-shoots from the older ones, so that a nation of towns, as it were, gradually spreads to an immense circumference round an original center. Forel describes such a nation of *Formica exsecta* which comprised more than two hundred nests, and covered a space of nearly two hundred square metres. Individual ants must here have been numbered by the million, and yet they all knew each other as friends—even those taken from farthermost nests—while they would admit no foreigners within their territory.

A still more remarkable case is recorded by McCook of what he calls an "ant town." The one he has described occurs in the Alleghany Mountains of North America, and consists of sixteen or seventeen hundred nests, which rise in cones to a height of from two to five feet. The ground below is riddled in every direction with subterranean passages of communication. The inhabitants are all on the most friendly terms, so that if any one nest is injured it is repaired by help from the other nests. Here, also, foreign ants of the same species were not tolerated; so that we should have an analogous case if all the inhabitants of Europe should be directly known to one another as friends, while an American or an Australian, on setting foot upon European ground, should be immediately set upon as an enemy.

Emotions.—The pugnacity, valor, and rapacity of ants are too well and generally known to require the narration of special instances of their display. With regard to the tenderer emotions, however, there is among observers a difference of opinion. Sir John Lubbock found that the species of ants on which he experimented are apparently deficient in feelings both of affection and of sympathy. He tried burying some specimens of *Lasius niger* beneath an ant-road; but none of the ants traversing the road made any attempt to release their imprisoned companions. He repeated the same experiment, with the same result, on various other species. Even when the friends in difficulty were actually in sight, it by no means followed that their companions would assist them. On imprisoning some friends in one bottle, the mouth of which was covered with muslin, and some strangers of the same species (*F. fusca*) in another bottle similarly protected, and placing both bottles in the nests, "the ants which were at liberty took no notice of the bottle containing their imprisoned friends. The strangers in the other bottle, on the other hand, excited them considerably." For days they crowded round this bottle, endeavoring to

gnaw through the muslin by which its mouth was closed. This on the seventh day they succeeded in doing, when they killed the imprisoned strangers. "The friends throughout were quite neglected," so that this experiment, as Sir John observes, seems to show that "in these curious insects hatred is a stronger passion than affection." This experiment always gave the same result in the case of this species; but, when tried with *Formica rufescens*, the ants took no notice of either bottle, and showed no signs either of affection or hatred; so that, as Sir John again observes, "one is almost tempted to surmise that the spirit of these ants is broken by slavery"—i. e., by the habit of keeping slaves.

But there is no lack of evidence to show, *per contra*, that the tenderer emotions have a place in ant-psychology. Even the hard-hearted species which Sir John Lubbock observed grew sympathetic toward sick or injured friends. Thus he observed that a specimen of *F. fusca*, which was congenitally destitute of antennæ, and which had been attacked by an ant of another species, excited the sympathy of a friend on being placed near her own nest. This friend "examined the poor sufferer carefully, then picked her up tenderly, and carried her away into the nest. It would have been difficult for any one who witnessed this scene to have denied to this ant the possession of humane feelings." Again, Moggridge has seen one ant carry another sick and apparently dead ant "down the twig which formed their path to the surface of the water, and, after dipping it in for a minute, carry it laboriously up again, and lay it in the sun to dry and recover."

But some species of ants seem habitually to show affection and sympathy even toward healthy companions in distress. Thus Belt writes of the *Eciton humata*, that "one day watching a small column of these ants, I placed a little stone on one of them to secure it. The next that approached, as soon as it discovered its situation, ran backward in an agitated manner, and soon communicated the intelligence to the others. They rushed to the rescue," and by their concerted action effected the release of their companion. Similarly ants of this species which Belt buried were always dug out by their friends. To quote one such instance, the ant which first found the buried one

> tried to pull her out, but could not. It immediately set off at a great rate, and I thought it had deserted her comrade, but it had only gone for assistance; for in a short time about a dozen ants came hurrying up, evidently fully informed of the circumstances of the case, for they made directly for their imprisoned comrade and set him free. I do not see how this could be instinctive. It was sympathetic help, such as men only among the higher mammalia show. The excitement and ardor with which they carried on their unflagging exertions for the rescue of their comrade could not have been greater if they had been human beings.

Ford and McCook have also observed displays of sympathy and affection by other species.

NURSING.—This may appropriately be considered in connection with the emotions, as it seems to imply something akin to maternal affection. The eggs will not develop into larvæ unless nursed, and the nursing is effected by licking the surface of the eggs, which under the influence of this process increase in size, or grow. In about a fortnight—during which time the workers carry the eggs from higher to lower levels of the nest, and *vice versa*, according to the circumstances of heat, moisture, etc.—the larvæ are hatched out, and require no less careful nursing than the eggs. The workers feed them by placing mouths together—the larvæ stretching out their heads to receive the nourishment after the manner of young birds. When fully grown the larvæ spin cocoons, and are then pupæ, or the "ants' eggs" of the pheasant-rearers. These require no food, but still need incessant attention with reference to warmth, moisture, and cleanliness. When the time arrives for their emergence as perfect insects, the workers assist them to get out of their larval cases by biting through the walls of the latter. When it emerges, the newly-born ant is inclosed in a thin membrane like a shirt, which has to be pulled off. "When we see," says Büchner, "how neatly and gently this is done, and how the young creature is then washed, brushed, and fed, we are involuntarily reminded of the nursing of human babies." The young ants are then educated. They are led about the nest and taught their various domestic duties. Later on they learn to distinguish between friends and foes; and when an ant's nest is attacked by foreign ants the young ones never join in the fight, but confine themselves to removing the pupæ. That the knowledge of hereditary enemies is not wholly instinctive is proved by the experiment of Forel, who put young uneducated ants of three different species into a glass case with pupæ of six other species—all the nine species being naturally hostile to one another. Yet the young ants did not quarrel, but worked together to tend the pupæ. When the latter hatched out, an artificial colony was formed of a number of naturally hostile species, all living together like the "happy families" of the showmen.

KEEPING APHIDES.—It is well and generally known that various species of ants keep aphides, as men keep milch-cows, to supply a nutritious secretion. Huber first observed this fact, and noticed that the ants collected the eggs of the aphides, and treated them with as much apparent care as they treated their own. When these eggs hatch out, the aphides are usually kept and fed by the ants. Sometimes the stems and branches on which they live are incased by the ants in clay walls, in which doors are left large enough to admit the ants, but too small to allow the aphides to escape. The latter are therefore imprisoned in regular stables. The sweet secretion is yielded to the ants by a process of "milking," which consists in the ants stroking the aphides with their antennæ.

Sir John Lubbock has made an interesting addition to our knowl-

edge respecting the habit in question, as practiced by a certain species of ant (*Lasius flavus*), which departs in a somewhat remarkable manner from the habit as practiced by other species. He says: "When my eggs hatched I naturally thought that the aphides belonged to one of the species usually found on the roots of plants in the nests of *Lasius flavus*. To my surprise, however, the young creatures made the best of their way out of the nest, and, indeed, were sometimes brought out of the nest by the ants themselves." Subsequent observation showed that these aphides, born from eggs hatched in the ants' nest, left the nest, or were taken from it, as soon as they were hatched, in order to live upon a kind of daisy which grew around the nest. Sir John then made out the whole case to be as follows:

> Here are aphides, not living in the ants' nests, but outside, on the leaf-stalks of plants. The eggs are laid early in October on the food-plant of the insect. They are of no direct use to the ants, yet they are not left where they are laid, where they would be exposed to the severity of the weather, and to innumerable dangers, but are brought into their nests by the ants, and tended by them with the utmost care through the long winter months until the following March, when the young ones are brought out and again placed on the young shoots of the daisy. This seems to me a most remarkable case of prudence. Our ants may not perhaps lay up food for the winter, but they do more, for they keep during six months the eggs which will enable them to procure food during the following winter.

As a supplement to this interesting observation, I may here append the following, which is due to Herr Nottebohm, who communicated it to Professor Büchner: This gentleman had a weeping-ash which was covered by millions of aphides. To save the tree, he one day in March cleaned and washed every branch and spray before the buds had burst, so removing all the aphides. There was no sign of the latter till the beginning of June, when he was surprised one fine sunny morning to see a number of ants running quickly up and down the trunk of the tree, each carrying up a single aphis to deposit it on the leaves, when it hurried back to fetch another. "After some weeks the evil was as great as ever. . . . I had destroyed one colony, but the ants replanted it by bringing new colonists from distant trees and setting them on the young leaves."

Aphides are not the only insects which are utilized by ants as cows. Gall-insects and cocci are kept in just the same way; but McCook observed that, where aphides and cocci are kept by the same ants, they are kept in separate chambers, or stalls. Caterpillars of the genus *Lycæna* have also been observed to be kept by ants for the sake of a sweet secretion which they supply.

Slavery.—The habit or instinct of keeping slaves obtains at least among three species of ant. It was first observed by P. Huber in *Formica rufescens*, which enslaves the species *F. fusca*, the members of which are appropriately colored black. The slave-making ants

attack a nest of *F. fusca* in a body; there is a great fight with much slaughter, and, if victorious, the slave-makers carry off the pupæ of the vanquished nest in order to hatch them out as slaves. When these pupæ hatch out, the young slaves begin their life of work, and seem to regard their masters' home as their own, for they never attempt to escape, and they fight in defense of the nest should it be attacked. The work that devolves upon the slaves differs according to the species which has enslaved them. In the nests of *F. sanguinea* the comparatively few captives are kept exclusively as household slaves, all the out-door work of foraging, slave-capturing, etc., being performed by the masters; and when for any reason a nest has to migrate, the masters carry their slaves in their jaws. On the other hand, *F. rufescens* assigns a much larger share of work to the slaves, which they capture in much larger numbers to take it. In this species the masters do no work whatsoever, unless the capturing of slaves be regarded as such. Therefore the whole community is entirely dependent upon its slaves; the masters are not able to make their own nests, to feed their own larvæ, or even to feed themselves; they die of starvation in the midst of favorite food if a slave should not be present to hand it in proper form. In order to confirm this observation (originally due to Huber) Lespès placed a piece of moistened sugar near a nest of these slave-makers. It was soon found by one of the slaves, which gorged itself and returned. Other slaves then came out and did likewise. Some of the masters next came out, and by pulling the legs of the feeding slaves reminded them that they were neglecting their duty. The slaves then immediately began to serve their masters to the sugar. Had they not done so, there is no doubt they would have been punished, for the masters bite the slaves when displeased with them. Forel and Darwin have also confirmed these observations of Huber. Indeed, the structure of the mouth in *F. rufescens* is such as to render self-feeding difficult, if not physically impossible. Its long and narrow jaws, admirably adapted to pierce the head of an enemy, do not admit of being used for feeding unless liquid food is poured into them from the mouth of a slave.

Ants do not appear to be the only animals of which ants make slaves; for there is at least one case in which these wonderful insects enslave insects of another species, which may therefore be said to stand to them in the relation of beasts of burden. The case to which I allude stands upon the authority of Audubon, who says that he has seen certain leaf-bugs used as slaves by ants in the forests of Brazil.

When these ants want to bring home the leaves which they have bitten off the trees, they do it by means of a column of these bugs, which go in pairs, kept in order on either side by accompanying ants. They compel stragglers to reënter the ranks, and laggards to keep up by biting them. After the work is done, the bugs are shut up within the colony and scantily fed.

WARS.—On the wars of ants a great deal might be said, as the facts of interest in this connection are very numerous; but for the sake of brevity I shall confine myself to giving only a somewhat meager account. One great cause of war is the plundering of ants' nests by the slave-making species. Observers all agree that, in the case of the so-called Amazon slave-making ant, this plundering is effected by a united march of the whole army composing a nest, directed against some particular nest of the species which they enslave. According to Lespès and Forel, single scouts or small companies are first sent out from the nest to explore in various directions for a suitable nest to attack. These scouts afterward serve as guides to the marauding excursion. When the scouts have been successful in discerning a suitable nest to plunder, and have completed their strategical investigations of the locality to their satisfaction—the latter process being often a laborious one, as it has special reference to the entrances of the nest, which are purposely made difficult to find by their architects—they return to their own fortress. Forel has seen them then walk about on the surface of this underground fortress for a long time, as if in consultation, after which some of them entered and again came out leading the host of warriors; these streamed from all the gateways, and ran about tapping each other with their heads and antennæ. They then formed into a column, composed of between one and two thousand individuals, and set out in orderly march to pillage the nest which had been examined by the scouts. According to Lespès, the column is about five metres long and fifty centimetres wide, marches at the rate of a metre per minute, and, on account of the distance which may have to be traversed, the march sometimes lasts for more than an hour. When they arrive at their destination a fierce battle begins, which, after raging for a time with much slaughter on both sides, generally, though not invariably, ends in the robbers gaining an entry. A barricade conflict then takes place below-ground, and, if the attack proves successful, the slave-making ants again stream out of the plundered nest, each ant carrying a stolen pupa. The Amazons can not climb, and this fact being known to the other ants, when they find that victory is on the side of the enemy, they devote themselves to saving what treasure they can by carrying their pupæ up the grasses and bushes surrounding the nest. When the marauders have obtained all the booty that they can, they set off on their homeward march, each carrying a pupa. They do not always follow the shortest road, but return exactly on the track by which they came, no doubt being guided entirely by the scent left on the ground from their previous march. When they arrive home they commit the pupæ to the care of the slaves. Forel found that a particular colony of slave-makers watched by him sent out forty-four marauding expeditions in thirty days, of which number twenty-eight were completely successful, nine partially so, and the remainder failures. The average booty obtained by a successful expedition was one thou-

sand pupæ, so that during a single summer the total number of pupæ captured by this colony might be put down at forty thousand.

Forel further tried the following experiment: He kept nests of two species of slave-making ants in two separate sacks, and when he saw that an expedition of a third species (Amazons) had found a slave-nest to plunder, and were fairly on their march toward it, he turned out one of his sacks upon the nest. A fight at once began between the slave-ants and sanguine ants which he had turned loose upon them. Then the vanguard of the Amazons came up; but, when they saw that the sanguines were already on the field, they drew back and awaited the approach of the main army. In close order this whole army then precipitated itself upon the already struggling host of sanguine ants. The latter, however, repulsed the attack, and the Amazons retired to reform. This done they made a second assault, which appearing as if it would end successfully, Forel, to complicate matters, poured upon the field his second sack containing the third species of slave-makers. All three species then fought together, till at last victory declared itself on the side of the Amazons. After overcoming their enemies they paused for a breathing-space before beginning the work of plunder. They then ravished the nest of the slave-ants, which, however, fought desperately, so that it seemed as though they courted death. They even followed the Amazons right up to their own nest, harassing them all the way. On arriving at the nest of the Amazons the slaves of the latter came out and assisted their masters to fight. These slaves were of two species—one being the same as that which was being plundered, so that these slaves were fighting for their masters against their own kind. Altogether, therefore, in that day's warfare there were six different species of ants engaged—three in alliance, and the rest in mutual antagonism.

The military tactics employed by the sanguine ants above mentioned are different from those employed by the Amazons. They do not seek to carry the fortress of the slave-ants by storm, but lay a regular siege, forming a complete circle round the nest, and facing it with jaws held fiercely open and antennæ thrown back. Being individually large and strong, they are able thus to confine the whole nest of slave-ants. A special guard is set upon the entrances of the nest, and this allows all slave-ants not carrying pupæ to pass, while it stops all the slave-ants which carry pupæ. The siege lasts till most of the slave-ants have thus been allowed to pass out, while all the pupæ are left behind. The forces then close in upon the entrances and completely rifle the nest of its pupæ—a few companies, however, being told off to pursue any slave-ants which may possibly have succeeded here and there in escaping with a pupa.

Wars are not confined to species of ants having slave-making habits. The agricultural ants likewise at times have fierce contests with one another. The importance of seeds to these insects, and the

consequent value which they set upon them, induce the animals, when supplies are scarce, to plunder one another's nests, prolonged warfare being the result. Thus Moggridge says: "By far the most savage and prolonged contests which I have witnessed were those in which the combatants belonged to two different colonies of the same species. . . . The most singular contests are those which are waged for seeds by *A. barbara*, when one colony plunders the stores of an adjacent nest belonging to the same species; the weaker nest making prolonged, though, for the most part, inefficient attempts to recover their property." In one case the predatory war lasted for forty-six days, during which time it became evident that the attacking nest was the stronger, for

> streams of ants laden with seeds arrived safely at the upper nest, while close observation showed that very few seeds were successfully carried on the reverse journey into the lower or plundered nest. Thus, when I fixed my attention on one of these robbed ants surreptitiously making its exit with the seed from the thieves' nest, and having overcome the oppositions and dangers met with on its way, reaching, after a journey which took six minutes to accomplish, the entrance to its own home, I saw that it was violently deprived of its burden by a guard of ants stationed there apparently for the purpose, one of whom instantly started off and carried the seed all the way back again to the upper nest. . . . After the 4th of March I never saw any acts of hostility between these nests, though the robbed nest was not abandoned. In another case of the same kind, however, where the struggle lasted thirty-two days, the robbed nest was at length completely abandoned.

Lastly, McCook records the history of an interesting engagement which he witnessed between two nests of *Tetramorium cæspitum* in the streets of Philadelphia, and which lasted for nearly three weeks. Although all the combatants belonged to the same species, friends were always distinguished from foes, however great the confusion of the fight. This fact is always observable in the case of battles between nests of the same species, and McCook thinks that the distinction appears to be effected in some way by contact of antennæ.

KEEPING PETS.—Many species of ants display the curious habit of harboring in their nests sundry kinds of other insects, which, so far as observation extends, are of no benefit to the ants, and which have therefore been regarded by observers as mere domestic pets. These pets are, for the most part, species which occur nowhere else except in ants' nests, and each species of pet is peculiar to certain species of ant. Beetles and crickets seem to be the more favorite kinds of insects, and these live on the best terms with their hosts, playing round the nests in fine weather, and retiring into them in stormy weather, while allowing the ants to carry them from place to place during migrations. It is evident, therefore, that ants not only tolerate these insects, but foster them; and, as it seems absurd to credit the ants with any mere fancy or caprice, such as that of keeping pets, it is per-

haps safest to suppose that these insects, like the aphides, are of some use to their masters, although we are not yet in a position to surmise what this use can be.

Sleep and Cleanliness.—It is probable that all ants enjoy periods of true slumber alternating with those of activity; but actual observations on this subject have only been made in the case of two or three species. McCook says that the harvesting ants of Texas sleep so soundly that they may be pretty severely stroked with a feather without being aroused; but they are immediately awakened by a sharp tap. On awakening they often stretch their limbs in a manner precisely resembling that of warm-blooded animals, and even yawn—the latter action being "very like that of the human animal; the mandibles are thrown open with the peculiar muscular strain which is familiar to all readers; the tongue is also sometimes thrust out." The ordinary duration of sleep in this species is about three hours.

Invariably on awakening, and often at other times, the ants perform, like many other insects, elaborate processes of washing and brushing. But, unlike other insects, ants assist one another in the performance of their toilet. The author just quoted describes the whole process in the genus *Atta*. The cleanser begins with washing the face of her companion, and then passes on to the thorax, legs, and abdomen.

> The attitude of the cleansed all this while is one of intense satisfaction, quite resembling that of a family dog when one is scratching the back of his neck. The insect stretches out her limbs, and, as her friend takes them successively into hand, yields them limp and supple to her manipulation; she rolls gently over on her side, even quite over on her back, and with all her limbs relaxed presents a perfect picture of muscular surrender and ease. The pleasure which the creatures take in being thus "combed" and "sponged" is really enjoyable to the observer. I have seen an ant kneel down before another and thrust forward the head drooping quite under the face, and lie there motionless, thus expressing, as plainly as sign-language could, her desire to be cleansed. I at once understood the gesture, and so did the supplicated ant, for she at once went to work.

Bates also has described similar facts with regard to ants of another genus—the *Ecitons*.

Play and Leisure.—The life of ants is not all work, or, at least, is not so in all species. Huber describes regular gymnastic sports as practiced by the species *pratensis*. They raise themselves on their hind-legs to wrestle and throw pretended antagonists with their fore-legs, run after each other, and seem to play at hide and seek. When one is victorious in a display of strength, it often seizes all the others in the ring, and tumbles them about like nine-pins. Forel has amply confirmed these observations of Huber, and says that the chasing, struggling, and rolling together upon the ground, pulling each other in and out of the entrances, etc., irresistibly reminded him of romping

boys at play. "I understand," he says, "that the matter must seem wonderful to those who have not witnessed it, particularly when we remember that sexual attraction can here play no part."

McCook and Bates also give similar accounts of the habits of play and leisure among species of the Western Hemisphere.

FUNERALS.—The habit of carrying their dead out and away from their nests is very general, if not universal, among ants; and, being no doubt due to sanitary requirements, has probably been developed as a beneficial instinct by natural selection. McCook says of the agricultural ants:

> All species whose manners I have closely observed are quite alike in their mode of caring for their own dead, and for the dry carcasses of aliens. The former they appear to treat with some degree of reverence, at least to the extent of giving them a sort of sepulture without feeding upon them. The latter, after having exhausted the juices of the body, they usually deposit together in some spot removed from the nest.

Experiments made on ants kept in confinement showed that the desire to remove dead companions was one of the strongest that they exhibited:

> So great was the desire to get rid of the dead outside the nest, that the bearers would climb up the smooth surface of the glass to the very top of the jar, laboriously carrying with them a dead ant. This was severe work, which was rarely undertaken except under the influence of this funereal enthusiasm. Falls were frequent, but patiently the little "undertaker" would follow the impulse of her instinct and try and try again. Finally the fact of a necessity seemed to dawn upon the ants (the jar being closed at the top so that they could not get out), and a portion of the surface opposite from the entrance to the galleries, and close up against the glass, was used as a burial-ground and sort of kitchen-midden, where all the refuse of the nest was deposited.

This author also records in his recently published work an interesting piece of information to which he was led by Mrs. Treat:

> A visit was paid to a large colony of these slave-makers (*F. sanguinea*), which is established on the grounds adjoining her residence at Vineland, New Jersey. I noticed that a number of carcasses of one of the slave species (*Formica fusca*) were deposited together quite near the gates of the nest. They were probably chiefly the dry bodies of ants brought in from recent raids. It was noticed that the dead ants were all of one species, and therefore Mrs. Treat informed me that the red slave-makers never deposited their dead with those of their black servitors, but always laid them by themselves, not in groups, but separately, and were careful to take them a considerable distance from the nest. One can hardly resist pointing out here another likeness between the customs of these social hymenoptera and those of human beings, certain of whom carry their distinctions of race, condition, or religious caste even to the gates of the cemetery, in which the poor body molders into its mother dust!—*Nineteenth Century.*

LUNAR LORE AND PORTRAITURE.

By F. E. FRYATT.

FROM the remotest periods of which we have quoted or written records, the moon has been an object of adoring and speculative contemplation. As the babe in the cradle, crowing and smiling, stretches out its tiny hands to grasp the shining flame of the distant candle, so the infant races of the world gazed at the radiant orb above them, seeking to grasp and penetrate its mystic beauties.

Nor is it to be marveled at, when we consider that this planet was the most brilliant and changeable, as well as the nearest and apparently largest celestial body that presented itself to their nightly view, and that in the clear, exquisite ether of Arabian skies, and the calm nights of India and Egypt, it shone among the heavenly host with a luster unknown to dwellers in the crowded cities of a northern clime.

But the children of these tropic lands did something more than gaze, speculate, and admire : with supreme patience they reared lofty towers and grand pyramids, and invented instruments which have led up step by step to the transit instrument, the micrometer, and the telescope of to-day. A college of astronomy was founded by the priesthood of Egypt, the worship of the moon growing out of their frequent use of her pictured or carved image in making their meteorological announcements to the people ; as, for instance, when the Nile was about to overflow, warning heralds were sent through the streets bearing aloft the familiar symbols of the river goddess, and a gilded figure of the moon in the phase it would present at the date of the expected rising.

In the course of time, the signification was forgotten, the symbol was worshiped, and finally what it represented deified. The moon no longer appeared to the unlettered populace as merely a brilliant lamp suspended from a revolving dome, and shining until extinguished by the waters of the ocean, but now was looked upon with awe as a region of sublime mysteries.

This veneration of the moon gradually spread with population to all parts of the world. We have records of ancient Chinese ceremonials ; relics found among Druidical remains in Western Europe ; accounts of astronomical picture-writings of a religious character, and lunar calendars of gold, silver, and stone, discovered in ancient temple-ruins in Mexico, Central and South America.

Among the buildings devoted to lunar worship may be mentioned the wonderful Temple of Diana at Ephesus, built at the combined expense of the nations of Asia, and the magnificent mansion of the moon adjoining the Temple of the Sun in ancient Cuzco ; this building was in form a pyramidal pavilion with doors and inclosures completely

incrusted with glittering silver. Within, on the southern wall, was a painting in white, presenting the moon as a beautiful woman; on either side along the eastern and western walls, on massive thrones of silver, were seated the dead queens of Peru, embalmed and arrayed in regal splendor.

In an elegant pavilion, covered with plates of the precious metal, adjoining the mansion, were apartments for the accommodation of her waiting-maids, the stars.

There was also an elaborate circular Temple of the Moon on a lofty hill near Quito, so arranged that the moonlight, falling through certain openings, shone directly on a silver image suspended from a blue roof emblazoned with stars.

Priesthoods and orders of priestesses existed in ancient Greece, Italy, India, Egypt, Britain, and America, fearful penalties attaching to broken vows or neglect of offices.

Many astronomers, whose quoted works are lost, flourished before Christ; their curious theories have been preserved in ancient writings of a later period. It is exceedingly interesting to trace, step by step, the changes of opinion wrought by gradual discovery in regard to the physical condition of the moon. This orb—variously supposed to be a brilliant disk-shaped body formed from mist congealed by fire; a mass of fiery and opaque elements; a circle of porous substance like pumice-stone, receiving light from a luminous ether; and a sphere, one half of which was burning—was finally pronounced by Anaxagoras, the Greek philosopher, in the year 500 B. C., to be an earth with mountains and valleys like our own.

For this opinion, and his belief that the moon was as large as the Peloponnesus, Anaxagoras was ridiculed by the learned men of his time. Six hundred years later, Plutarch supported the views of his ancient predecessor; but it was not until the application of the first telescope that any certain knowledge of the planet was gained. This instrument caused a complete revolution of ideas in astronomy. Galileo's plains, mountains, and valleys, were facts, whereas those of Anaxagoras had been matters of conjecture. Imagination soon peopled the moon with a peculiar race of beings, covered it with grand forests and cities, and all that pertains to a habitable world. Fortifications were discovered; consequently, the Lunarians were a warlike people. Certain bright points on the dark portion of the moon's disk were proclaimed to be conflagrations, or volcanic eruptions, or perhaps fire-works in honor of some lunar event.

A German astronomer proposed the building of an immense triangle on the plains of Siberia as a means of mathematical correspondence with the moon's inhabitants, believing they would build one in reply. A brother scientist, commenting on this novel signal-service, naïvely declared that "many more foolish projects had been carried out successfully."

Improved instruments have demonstrated that life, as we understand it, is impossible on the lunar body, revealing to us that it is composed of rocks and matter of a highly reflective character; its surface being broken up by ranges of lofty, perpendicular mountains, craters of elevation, precipitous caves and hollows; that the dark plains are the beds of oceans long ago evaporated or withdrawn into the interior of the planet; that it is subject to enormous degrees of heat and cold, has no water or apparent atmosphere, and, if so, neither wind, wave, nor sound.

Nothing varies the monotony of the long days and nights composing the lunar year, save the changing positions of the intensely black shadows falling from hills and mountains that cut off or fling back into space the white light of the sun; or the swift, silent fall of the crumbling walls of some hollow crater.

On looking at the moon through the telescope for the first time, one is struck by the melancholy character of its broken yet shining surface. Desolate plains are seen stretching away from the central view to the dazzling sunlit edge where, under the immedate solar glare, they seem sheeted with everlasting snow. To the right, as they gradually approach the region of darkness, the white softens into the greenish gray of a sandy desert.

But, ho! what tracks are these like the footprints of huge camels? Has some celestial caravan passed this way and disappeared from sight in the far south? Shall we see another wending its slow way after?

And yonder—another marvel—a fountain of silver sending from its argent depths rivers of precious metal to wander over sandy plains! Will the wonders never cease? Beyond, on the brilliant terminator, are promontories of pearly luster jutting out into seas of darkness, and, remoter still, pendent stars shining over ebon gulfs!

Gentle astronomer, increase your magnifying, for we long to investigate, space by space, this moon whose beauties we have never known before!

Ah, the footprints are footprints no longer—they are cup-shaped hollows innumerable! These drifts, as of snow, are ranges of mountains, and the promontories and pendent stars are crags and mountain-tops just catching the rays of dawn. Down their steep sides lie the shadows of night; the topmost peaks alone have caught the glory! And beyond is the night-side of the moon, illumined by dim earth-light.

The power is increased again, and now we are looking down into a crater, and behold! one, two, three mountains rising from its central depths; their peaks hardly reach the level of its ring-shaped summit!

Here is another crater, with a solitary peak rising from its bottom. See, down below, piles of rocks are lying around its base. Three miles deep, by measurement, what awful gulfs of darkness these at the new

moon, when no light falls within their silent hollows! What reservoirs of fiercest heat when, like a giant eye, the sun glares down and floods their unsheltered spaces!

Let us turn once more to those bright fountains and rivers of silver, astronomically called "rilles." Here they are, brilliant as ever; but we can learn nothing of their nature by gazing at them. The astronomer will tell you the latest theory—namely, that when the moon's crust was cooling, ages ago, it contracted, causing immense corrugations, wrinkles, and nodules, and in many places deep rents, admitting water to the heated nucleus, producing volcanic action; in many of these fissures rose up molten matter, filling the central openings to the brim, and extending all the length of the cracks.

You have already noticed that besides the craters there are innumerable craterlets. Your guide will explain again—referring to some great authority—the fanciful and plausible theory that these were the result of downfalls of meteoric rain when the lunar crust was still in the plastic state.

Let us observe the plains again: near the left border, under the sun-glare, they are too brilliant for definition of detail; near the central view their greenish-gray surfaces may be examined in the apparent twilight of the moon. Their seemingly smooth character and color prove them to be beds of oceans of the past lunar ages. These marine bottoms are not smooth in reality, but are seamed and traversed by ranges of hills and mountains, and craters thousands of feet deep! Did these, like monster mouths, swallow the remnants of the evaporating oceans?

The longer one studies this lonely globe, so beautiful in its desolation, the more real does it become to the eye. Here rise veritable mountains casting their black shadows on the plains. There stretch deserts thousands of miles in length, visible throughout all their breadth, for there is little if any perspective on the moon.

To the east is reigning the brilliant lunar day, so long, so fierce, so hot; beyond it is evening, with sunset touching the mountain-peaks on the terminator; in the remotest west, midnight!

This is more than one can see on one's own terrestrial ball, where the vision is bounded by atmosphere, and objects "by degrees grow beautifully less."

One must not look at the full moon to view all these wonders, for seen through the telescope it is merely a brilliant, dazzling sphere; mountains, valleys, and plains are flooded with intensest light; no shadows fall; the white glitter is intolerable!

It must be viewed in six phases: the three-days-old crescent, five-days' old, seven days' old or first quarter, the last quarter, and the last three days of the old moon; thus may be seen the four visible sevenths of the lunar globe, all that is ever seen by mortal eye.

From time immemorial the graphic art has been employed in repre-

senting the moon according to the prevailing theory of the time, as seen by the naked eye or through the telescope. In the picture-writings of both continents, in their carvings and metal castings, were seen the first rude presentations of the planet in her various phases.

The first astronomical moon-drawing is attributed to Anaxagoras; it was probably executed more than twenty-three centuries ago. Since his time numberless drawings have been made, all more or less imperfect. In 1609, Galileo, from observations made with a telescope of his own invention, constructed the first lunar map, which is valuable only as marking the first great advance toward precise knowledge of the moon's surface.

Scheiner, a German professor, and Schirlaus, made numerous sketches of a like character; during the same century Langrenus executed special drawings of different points on the moon, naming them after celebrated personages.

About the year 1647 appeared the "Selenographia," a work by Hevelius, of Dantzic, wherein was the first lunar map at all approaching correctness. Although Father Riccioli, of Bologna, published a chart in 1651, and Dominic Cassini another in 1680, fuller as to detail, Hevelius's chart was considered the best authority for one hundred years after its issue, his knowledge of drawing contributing greatly to its success.

In 1775 appeared Tobias Mayer's small lunar chart, the most accurate yet published, and consulted as such until 1824. The first scientific attempt to delineate the characteristic features of the moon in detail was made by Lohrmann, a land-surveyor in Dresden: he intended to publish a chart on a large scale in twenty-five sections, but failing eyesight compelled him to forego his ambitious project; he, however, executed a fine lunar map, fifteen and a quarter inches in diameter, in 1838.

Schroeter, of Lilienthal, labored with the greatest patience, making a long series of observations, but, owing to a lack of graphic skill, his "Selenographische Fragmente" was not a true exponent of his ideas.

In 1837 appeared Beer and Mädler's "Der Monde," one of the most valuable contributions to astronomical literature; the chart accompanying it shows an immense amount of detail, all the principal objects seen through the telescope being given in outline. Webb's "Map of the Moon," reduced from this chart, is of great value to the student, retaining as it does all the most important features and omitting confusing detail.

The most interesting and wonderful chart yet published is that recently completed by Schmidt, of Athens, the result of more than a quarter of a century's observations of the moon, and for which the author made more than a thousand drawings.

The most diffuse and clearly illustrated work published within the

last decade is Neison's "Moon," the accompanying chart in sections giving the principal features of the planet's surface. Nasmyth and Carpenter's "Moon," illustrated by fine photographs of prominent insulated peaks, mountain-ranges, and crateriform mountains, and Proctor's "Motions, Aspect, Scenery, and Physical Condition of the Moon," furnish delightful and instructive text to the general reader.

Very beautiful drawings of single craters, viewed under high power, have been made by Secchi, Nasmyth, and Carpenter. Bertch, Arnauld, Temple, and Harriot, a young English astronomer, have given us topographical lunar drawings of considerable merit.

The greatest change in lunar illustration occurred in the application of the telescope to photography. The moon, sighted by a telescope provided with a meniscus lens for the collection of the actinic rays, and kept in the field by the driving-clock, casts her image on a sensitive plate, which, being developed, gives all the numerous details of the lunar surface—dimly and minutely, to be sure, but capable of enlargement and printing to apparent life-size.

Draper photographed the moon in 1840; Bond, in 1850; De La Rue and Rutherfurd, in 1857, the former discovering that the pictures could be combined in the stereoscope so as to appear globular. Photographic representations of the moon, in her various phases, are eminently picturesque, though lacking distinct detail; they are, however, correct, for, granted that the apparatus is properly adjusted, the sun paints with perfect truth.

Neison's maps of the moon were first done in water-color. Some have also been done in this vehicle by the "Moon Committee" of the Royal Astronomical Society of London." It has been reserved for Henry Harrison, a young American astronomer and artist, to paint the first and only true telescopic portrait of the moon in oil-colors.

"Not difficult to do!" exclaims the uninitiated observer.

"Impossible!" returns the scientist. "No one can paint the moon in detail."

Nevertheless, our æsthetic astronomer set to work to paint the six phases, which would give a portrait not only picturesque, but so true to details and coloring that it could be offered to the scrutiny of eyes long practiced in the nightly study of the orb itself—eyes that would be quick to detect the absence of the smallest crater, the presence of a superfluous peak.

After the professional duties of the day, Mr. Harrison, when the weather was propitious, passed his time in making observations of the heavens. Seated at the telescope, he would pass hour after hour, studying the surface of the lunar orb.

On one of these occasions, a summer evening, singularly calm and clear, his wife joined him. Sitting for some time completely absorbed in the brilliant spectacle, she at last exclaimed: "Henry, paint that, if you can; it is beautiful beyond description!"

The thought had not then occurred to him. Now his wife's fanciful challenge awakened a desire to paint the moon in colors; for, as the most exquisite portrait in black and white can not express the bloom of lip and cheek, or the burnished gold of sunny tresses, neither could the various astronomical drawings now in existence express the beautiful gradations of light, the delicate tinting of the gray-green plains, the brilliant peaks and sunlit edge that make the telescopic moon the most interesting of celestial bodies.

Hitherto the human face and form had engaged his pencil: he could command sittings of his subject where and when he chose; direct the light and shade; arrange the drapery, select the pose: but here was to be another order of affairs; a willful, fitful queen, subject to no human wishes, obedient to no mortal command. There were only two evenings in the month in which to study the chosen phase—on one of them or both her Majesty might command the vapors of the air and veil herself in impenetrable cloud. Another month she might summon the forces of the winds, and dance with them a demon's dance upon the telescopic mirror; and, on the next night, when the chosen phase was past, appear serenely beautiful upon a field of stainless blue.

It may be fairly asked how the artist, contending with so many difficulties, could paint a faithful portrait at all. As it would be impossible in the moon's short sittings, if one may use the term, to catch and fix accurately the varied details that crowd its surface with the pencil alone, Mr. Harrison resorted, as a first step, to photographic aid. Taking Rutherfurd's negative of the three-days-old crescent, he enlarged it to the desired size by means of an oxyhydrogen light, throwing the image from the glass to his canvas. Thereon he sketched the outlines of the craters, plains, and mountain-ranges, as the enlarged negative indistinctly presented them. Then, by the light of a lantern suspended from the observatory roof, from time to time consulting the image of the moon mirrored in the telescope, he sharpened every detail, marking out the intensely black shadows and the equally intense high lights on the topmost peaks of the terminator, the dazzling edge, and the gradations of tint on the far-stretching plains.

Slowly—for eighteen months rolled by before the first phase was finished—pencil and pigment, guided by artist eye and hand, did their work, and there stood a faithful portrait of the three-days-old crescent, twenty-one inches in diameter, showing the terminator at Messier.

The edge toward the left is brilliantly illuminated by the sun, whose proximity casts a yellowish tint over the plains, that gradually fades into grayish-green in the shadows of night on the right edge or terminator. On the remainder of the disk, faintly illumined by earth-light, may be dimly seen outlines of the Apennine ranges, and the craters of Copernicus and Tycho.

The brilliant convexity of the moon is well thrown out by the clear

dark-blue of the sky in which it floats, the painted revelation of the wonders of a sister world. Plainer than words, this colored image tells the story of an activity of tempests, and bubbling caldrons of fire long since burned out; of oceans evaporated and drawn into the deepest depths of a dying world—of present silence and empty desolation!

Encouraged by the approval of famous scientists, who have examined and testified to the correctness and beauty of this first phase of the moon, Mr. Harrison has completed a second phase, and is at work on the remaining pictures, which are in various stages of progression.

Among the prominent features represented as seen on the telescopic moon at the first quarter may be mentioned the Mare Crisium, one of the darkest of all the regularly bordered mares or dark plains. Crisium shows a surface of a gray tint tinged with green. At times it is curiously dotted and streaked with light. The floor is traversed by ridges crossing each other and throwing up small peaks. At the first quarter appears Messier, on the terminator of the three-days-old crescent. Messier is a fine crater-plain, nine miles in diameter, inclosed by a bright mountain-wall. To the southeast rise the walls of Catharina, in some places reaching a height of sixteen thousand feet above the interior plain, which, under the highest magnifying power, shows a surface broken up into mounds, ridges, hills, and craterlets.

Lying to the northwest appears the Mare Fœcunditatis, the largest of the western mares or sea-beds, covering an area of one hundred and sixty thousand square miles, and penetrating, in bay-like indentations, into the mountain-ranges southward, Mare Tranquillitatis and Serenitatis, the latter one of the most prominent gray plains seen at the first quarter. The entire central portion of this mare shows a decided light-green tinge.

At the last quarter the most striking feature is Copernicus, the grandest ring-plain on the northern quadrant, and one of the most instructive. Its vast walls rise nearly twelve thousand feet above the level of the plateau, showing fifty magnificent peaks that shine at certain seasons like a crown of pearls on a radiant background. The central cones attain a height of nearly three thousand feet. On the inner side the walls fall abruptly in terraces to the floor, while, without, they slope gradually, and are broken into confused ridges, spreading away from their bases into hill and mountain chains.

Aristarchus, a brilliant ring-plain, is also visible at the last quarter; its broad, terraced walls rise twenty-six hundred feet above the moon's surface, and seven thousand five hundred above its own interior floor, nearly in the center of which stand two peaks and a small crater, the central peak being the most brilliant point visible on the moon. Among the bays, so called, seen on this quarter, is the Sinus Iridum, a dark, semicircular level, bordered by the magnificent cliffs of one of the most stupendous highlands of the moon, whose crest sends up at cer-

tain points towering peaks from fifteen to twenty thousand feet above the level of the dark plain.

The Mare Imbrium, also lying in the north quadrant, is the largest of the dark ring-plains of the moon. The lunar Carpathian and Apennine ranges bound it on the south, the Caucasus and Alps on the west, and on the north the lofty highlands of Plato and the Sinus Iridum. It has a length of seven hundred and fifty miles, and a breadth of six hundred and seventy-eight.

One of the most wonderful and mysterious features of the moon, and seen on the southern quadrant, is Tycho, the center of the principal streak system. From its mountain-walled plain issue streams of radiance like rivers of silver; some of these "rilles" flow for a length of a thousand miles. The southern portion of the moon is a mass of old craters, ring-plains, valleys, hills, and ridges; with its radiant streak system and diversity of formations it is the most interesting part of the lunar surface.

When completed, this series of paintings will present not only a worn-out world in miniature, but, if one may credit the great astronomers of our day, the painted prophecy of the far-off future of our own earth, when it shall have cooled off, and all the bustling, battling throngs of humanity be as its own clay!

THE VISIONS OF SANE PERSONS.

By FRANCIS GALTON.

IN the course of some recent inquiries into visual memory, I was greatly struck by the frequency of the replies in which my informants described themselves as subject to "visions." Those of whom I speak were sane and healthy, but were subject notwithstanding to visual presentations, for which they could not often account, and which in a few cases reached the level of hallucinations. This unexpected prevalence of a visionary tendency, among persons who form a part of ordinary society, seems to me suggestive and worthy of being put on record. In a previous article* I spoke of the faculty of summoning scenes at will, with more or less distinctness, before the visual memory; in this I shall speak of the tendency among sane and healthy persons to see images flash unaccountably into existence.

Many of my facts are derived from personal friends of whose accuracy I have no doubt. Another group comes from correspondents who have written at length with much painstaking, and whose letters

* See a previous article on "Mental Imagery," "Popular Science Monthly," vol. xviii, p. 64.

appear to me to bear internal marks of scrupulous truthfulness. A third part has been collected for me by many kind friends in many countries, each of whom has made himself or herself an independent center of inquiry ; and the last, and much the most numerous portion, consists of brief replies by strangers to a series of questions contained in a circular that I drew up. I have gone over all this matter with great care, and have cross-tested it in many ways while it was accumulating, just as any conscientious statistician would, before I began to form conclusions. I was soon convinced of its substantial trustworthiness, and that conviction has in no way been shaken by subsequent experience. In short, the evidence of the four groups I have just mentioned is quite as consistent as could have been reasonably desired.

The lowest order of phenomena that admit of being classed as visions are the "Number forms" to which I have drawn attention on more than one occasion, but to which I must again very briefly allude. They are an abiding mental peculiarity in a certain proportion of persons (say five per cent.), who are unable as adults, and who have been ever unable as far back as they can recollect, to think of any number without referring it to its own particular habitat in their mental field of view. It there lies latent, but is instantly evoked by the thought or mention of it, or by any mental operation in which it is concerned. The thought of a series of consecutive numbers is therefore attended by a vision of them arranged in a perfectly defined and constant position, and this I have called a "Number form." Its origin can rarely be referred to any nursery diagram, to the clock-face, or to any incident of childhood. Nay, the form is frequently unlike anything the child could possibly have seen, reaching in long vistas and perspectives, and in curves of double curvature. I have even had to get wire models made by some of my informants in explanation of what they wished to convey. The only feature that all the forms have in common is their dependence in some way or other upon the method of verbal counting, as shown by their angles and other divisions occurring at such points as those where the 'teens begin, at the twenty's, thirty's and so on. The forms are in each case absolutely unchangeable, except through a gradual development in complexity. Their diversity is endless, and the Number forms of different men are mutually unintelligible.

These strange "visions," which are extremely vivid in some cases, are almost incredible to the vast majority of mankind, who would set them down as fastastic nonsense, but they are familiar parts of the mental furniture of the rest, where they have grown naturally, and where they remain unmodified and unmodifiable by teaching. I have received many touching accounts of their childish experiences from persons who see the Number forms, and the other curious visions of which I shall speak. As is the case with the color-blind, so with these

seers. They imagined at first that everybody else had the same way of regarding things as themselves. Then they betrayed their peculiarities by some chance remark which called forth a stare of surprise, followed by ridicule and a sharp scolding for their silliness, so that the poor little things shrunk back into themselves, and never ventured again to allude to their inner world. I will quote just one of many similar letters as a sample. I received this, together with much interesting information, immediately after a lecture I gave last autumn to the British Association at Swansea,* in which I had occasion to speak of the Number forms. The writer says :

> I had no idea, for many years, that every one did not imagine numbers in the same positions as those in which they appear to me. One unfortunate day I spoke of it, and was sharply rebuked for my absurdity. Being a very sensitive child, I felt this acutely, but nothing ever shook my belief that, absurd or not, I always saw numbers in this particular way. I began to be ashamed of what I considered a peculiarity, and to imagine myself, from this and various other mental beliefs and states, as somewhat isolated and peculiar. At your lecture the other night, though I am now over twenty-nine, the memory of my childish misery at the dread of being peculiar came over me so strongly that I felt I must thank you for proving that, in this particular, at any rate, my case is most common.

The next form of vision of which I will speak is the instant association of color with sound, which characterizes a small percentage of adults, but apears to be rather common, though in an ill-developed degree, among children. I can here appeal not only to my own collection of facts, but to those of others, for the subject has latterly excited some interest in Germany. The first widely known case was that of the brothers Nussbaumer, published in 1873 by Professor Bruhl, of Vienna, of which the English reader will find an account in the last volume of Lewis's "Problems of Life and Mind," page 280. Since then many occasional notices of similar associations have appeared, but I was not aware that it had been inquired into on a large scale by any one but myself. However, I was gratified by meeting with a pamphlet a few weeks ago, just published in Leipsic by two Swiss investigators, Messrs. Bleuler and Lehmann. Their collection of cases is fully as large as my own, and their results in the more important matters are similar to mine. One of the two authors had the faculty very strongly, and the other had not ; so they worked conjointly with advantage. As my present object is to subordinate details to the general impression that I wish to convey of the visionary tendency of certain minds, I will simply remark, first, that the persistence of the color association with sounds is fully as remarkable as that of the Number form with numbers. Secondly, that the vowel-sounds chiefly evoke them. Thirdly, that the seers are invariably most minute in their description of the precise tint and hue of the

* See "Fortnightly Review," September, 1880.

color. They are never satisfied, for instance, with saying "blue," but will take a great deal of trouble to express or to match the particular blue they mean. Lastly, no two people agree, or hardly ever do so, as to the color they associate with the same sound. I have one of the most extraordinary diagrams of these color associations that has, I suppose, ever been produced. It has been drawn by Mr. J. Key, of Graham's Town, South Africa. He sent me in the first instance a communication on the subject, which led to further correspondence, and eventually to the production of this diagram of colors in connection with letters and words. I have no reason to doubt its trustworthiness, and am bound to say that, strange as it looks, and elaborate as it is, I have other written accounts that almost match it.

A third curious and abiding fantasy of certain persons is invariably to connect visualized pictures with words, the same picture to the same word. I have collected many cases of this, and am much indebted to the authoress, Mrs. Haweis, who sees these pictures, for her kindness in sketching some of them for me, and her permission to use her name in guarantee of their genuineness. She says:

> Printed words have always had faces to me: they had definite expressions, and certain faces made me think of certain words. The words had *no* connection with these except sometimes by accident. The instances I give are few and ridiculous. When I think of the word Beast, it has a face something like a gargoyle. The word Green has also a gargoyle-face, with the addition of big teeth. The word Blue blinks and looks silly, and turns to the right. The word Attention has the eyes greatly turned to the left. It is difficult to draw them properly, because, like "Alice's" "Cheshire cat," which at times became a grin without a cat, these faces have expression without features. The expression, of course [note the *naïve* phrase, "of course."—F. G.], depends greatly on those of the letters, which have likewise their faces and figures. All the little a's turn their eyes to the left; this determines the eyes of Attention. Ant, however, looks a little down. Of course, these faces are endless as words are, and it makes my head ache to retain them long enough to draw.

Some of the figures are very quaint. Thus the interrogation "what?" always excites the idea of a fat man cracking a long whip. They are not the capricious creations of the fancy of the moment, but are the regular concomitants of the words, and have been so as far back as the memory is able to recall.

When in perfect darkness, if the field of view be carefully watched, many persons will find a perpetual series of changes to be going on automatically and wastefully in it. I have much evidence of this. I will give my own experience the first, which is striking to me, because I am very unimpressionable in these matters. I visualize with effort; I am peculiarly inapt to see "after-images," "phosphenes," "light-dust," and other phenomena due to weak sight or sensitiveness; and, again, before I thought of carefully trying, I should have emphatically declared that my field of view in the dark was essentially of a

uniform black, subject to an occasional light-purple cloudiness and other small variations. Now, however, after habituating myself to examine it with the same sort of strain that one tries to decipher a sign-post in the dark, I have found out that this is by no means the case, but that a kaleidoscopic change of patterns and forms is continually going on, but they are too fugitive and elaborate for me to draw with any approach to truth. My deficiencies, however, are well supplied by other drawings in my possession. They are by the Rev. George Henslow, whose visions are far more vivid than mine. His experiences are not unlike those of Goethe, who said, in an often-quoted passage, that, whenever he bent his head and closed his eyes and thought of a rose, a sort of rosette made its appearance, which would not keep its shape steady for a moment, but unfolded from within, throwing out a succession of petals, mostly red, but sometimes green, and that it continued to do so without change in brightness and without causing him any fatigue so long as he cared to watch it. Mr. Henslow, when he shuts his eyes and waits, is sure, in a short time, to see before him the clear image of some object or other, but usually not quite natural in its shape. It then begins to change from one object to another, in his case, also, for as long a time as he cares to watch it. Mr. Henslow has zealously made repeated experiments on himself, and has drawn what he sees. He has also tried how far he is able to mold the visions according to his will. In one case, after much effort, he contrived to bring the imagery back to its starting-point, and thereby to form what he terms a "visual cycle." The following account is extracted and condensed from his very interesting letter:

The first image that spontaneously presented itself was a cross-bow; this was immediately provided with an arrow, remarkable for its pronounced barb and superabundance of feathering. Some person, but too indistinct to recognize much more of him than the hands, appeared to shoot the arrow from the bow. The single arrow was then accompanied by a flight of arrows from right to left, which completely occupied the field of vision. These changed into falling stars, then into flakes of a heavy snow-storm; the ground gradually appeared as a sheet of snow where previously there had been vacant space. Then a well-known rectory, fish-ponds, walls, etc., all covered with snow, came into view most vividly and clearly defined. This somehow suggested another view, impressed on his mind in childhood, of a spring morning, brilliant sun, and a bed of red tulips: the tulips gradually vanished except one, which appeared now to be isolated and to stand in the usual point of sight. It was a single tulip, but became double. The petals then fell off rapidly in a continuous series until there was nothing left but the pistil, but (as is almost invariably the case with his objects) that part was greatly exaggerated. The stigmas then changed into three branching brown horns; then into a knob, while the stalk changed into a stick. A slight bend in it seems to have suggested a center-bit; this passed into a sort of pin passing through a metal plate; this again into a lock, and afterward into a nondescript shape, distantly suggestive of the original cross-bow. Here Mr. Henslow endeavored to force his will upon the visions, and to reproduce the cross-bow, but the first attempt was an utter failure. The figure

changed into a leather strap with loops, but while he still endeavored to change it into a bow the strap broke, the two ends were separated, but it happened that an imaginary string connected them. This was the first concession of his automatic chain of thoughts to his will. By a continued effort the bow came, and then no difficulty was felt in converting it into the cross-bow and thus returning to the starting-point.

I have a sufficient variety of cases to prove the continuity between all the forms of visualization, beginning with an almost total absence of it, and ending with a complete hallucination. The continuity is, however, not simply that of varying degrees of intensity, but of variations in the character of the process itself, so that it is by no means uncommon to find two very different forms of it concurrent in the same person. There are some who visualize well and who also are seers of visions, who declare that the vision is not a vivid visualization, but altogether a different phenomenon. In short, if we please to call all sensations due to external impressions "*direct*," and all others "*induced*," then there are many channels through which the induction may take place, and the channel of ordinary visualization in the persons just mentioned is very different from that through which their visions arise.

The following is a good instance of this condition. A friend writes :

These visions often appear with startling vividness, and, so far from depending on any voluntary effort of the mind, they remain when I often wish them very much to depart, and no effort of the imagination can call them up. I lately saw a framed portrait of a face which seemed more lovely than any painting I have ever seen, and again I often see fine landscapes which bear no resemblance to any scenery I have ever looked upon. I find it difficult to define the difference between a waking vision and a mental image, although the difference is very apparent to myself. I think I can do it best in this way: If you go into a theatre and look at a scene, say of a forest by moonlight, at the back part of the stage, you see every object distinctly and sufficiently illuminated (being thus unlike a mere act of memory), but it is nevertheless vague and shadowy, and you might have difficulty in telling afterward all the objects you have seen. This resembles a mental image in point of clearness. The waking vision is like what one sees in the open street in broad daylight, when every object is distinctly impressed on the memory. The two kinds of imagery differ also as regards voluntariness, the image being entirely subservient to the will, the visions entirely independent of it. They differ also in point of suddenness, the images being formed comparatively slowly as memory recalls each detail, and fading slowly as the mental effort to retain them is relaxed; the visions appearing and vanishing in an instant. The waking visions seem quite close, filling as it were the whole head, while the mental image seems farther away in some far-off recess of the mind.

The number of persons who see visions no less distinctly than this correspondent is much greater than I had any idea of when I began this inquiry. I have in my possession the sketch of one, prefaced by a description of it by Mrs. Haweis. She says :

All my life long I have had one very constantly recurring vision, a sight which came whenever it was dark or darkish, in bed or otherwise. It is a flight of pink roses floating in a mass from left to right, and this cloud or mass of roses is presently effaced by a flight of "sparks" or gold speckles across them. The sparks totter or vibrate from left to right, but they fly distinctly upward: they are like tiny blocks, half gold, half black, rather symmetrically placed behind each other, and they are always in a hurry to efface the roses: sometimes they have come at my call, sometimes by surprise, but they are always equally pleasing. What interests me most is, that when a child under nine the flight of roses was light, slow, soft, close to my eyes, roses so large and brilliant and palpable that I tried to touch them: the *scent* was overpowering, the petals perfect, with leaves peeping here and there, texture and motion all natural. They would stay a long time before the sparks came, and they occupied a large area in black space. Then the sparks came slowly flying, and generally, not always, effaced the roses at once, and every effort to retain the roses failed. Since an early age the flight of roses has annually grown smaller, swifter, and farther off, till by the time I was grown up my vision had become a speck, so instantaneous that I had hardly time to realize that it was there before the fading sparks showed that it was past. This is how they still come. The pleasure of them is past, and it always depresses me to speak of them, though I do not now, as I did when a child, connect the vision with any elevated spiritual state. But, when I read Tennyson's "Holy Grail," I wondered whether anybody else had had my vision—"Rose-red, with beatings in it." I may add, I was a London child who never was in the country but once, and I connect no particular flowers with that visit. I may almost say that I had never seen a rose, certainly not a quantity of them together.

A common form of vision is a phantasmagoria, or the appearance of a crowd of phantoms, perhaps hurrying past like men in a street. It is occasionally seen in broad daylight, much more often in the dark; it may be at the instant of putting out the candle, but it generally comes on when the person is in bed, preparing to sleep, but is by no means yet asleep. I know no less than three men, eminent in the scientific world, who have these phantasmagoria in one form or another. A near relative of my own had them in a marked degree. She was eminently sane, and of such good constitution that her faculties were hardly impaired until near her death at ninety. She frequently described them to me. It gave her amusement during an idle hour to watch these faces, for their expression was always pleasing, though never strikingly so. No two faces were ever alike, and they never resembled that of any acquaintance. When she was not well the faces usually came nearer to her, sometimes almost suffocatingly close. She never mistook them for reality, although they were very distinct. This is quite a typical case, similar in most respects to many others that I have.

A notable proportion of sane persons have had not only visions, but actual hallucinations of sight, sound, or other sense, at one or more periods of their lives. I have a considerable packet of instances contributed by my personal friends, besides a large number communicated

to me by other correspondents. One lady, a distinguished authoress, who was at the time a little fidgeted, but in no way overwrought or ill, said that she saw the principal character of one of her novels glide through the door straight up to her. It was about the size of a large doll, and it disappeared as suddenly as it came. Another lady, the daughter of an eminent musician, often imagines she hears her father playing. The day she told me of it the incident had again occurred. She was sitting in a room with her maid, and she asked the maid to open the door that she might hear the music better. The moment the maid got up the hallucination disappeared. Again, another lady, apparently in vigorous health, and belonging to a vigorous family, told me that during some past months she had been plagued by voices. The words were at first simple nonsense; then the word "pray" was frequently repeated; this was followed by some more or less coherent sentences of little import, and finally the voices left her. In short, the familiar hallucinations of the insane are to be met with far more frequently than is commonly supposed, among people moving in society and in normal health.

I have now nearly done with my summary of facts; it remains to make a few comments on them.

The weirdness of visions lies in their sudden appearance, in their vividness while present, and in their sudden departure. An incident in the Zoölogical Gardens struck me as a helpful simile. I happened to walk to the seal-pond at a moment when a sheen rested on the unbroken surface of the water. After waiting a while I became suddenly aware of the head of a seal, black, conspicuous, and motionless, just as though it had always been there, at a spot on which my eye had rested a moment previously and seen nothing. Again, after a while, my eye wandered, and, on its returning to the spot, the seal was gone. The water had closed in silence over its head without leaving a ripple, and the sheen on the surface of the pond was as unbroken as when I first reached it. Where did the seal come from, and whither did it go? This could easily have been answered if the glare had not obstructed the view of the movements of the animal under water. As it was, a solitary link in a continuous chain of actions stood isolated from all the rest. So it is with the visions; a single stage in a series of mental processes emerges into the domain of consciousness. All that precedes and follows lies outside of it, and its character can only be inferred. We see in a general way, that a condition of the presentation of visions lies in the over-sensitiveness of certain tracks or domains of brain-action, and the under-sensitiveness of others; certain stages in a mental process being vividly represented in consciousness while the other stages are unfelt. It is also well known that a condition of partial hyperæsthesia and partial anæsthesia is a frequent functional disorder, markedly so among the hysterical and hypnotic, and an organic disorder among the insane. The abundant facts that I have collected

show that it may also coexist with all the appearances of good health and sober judgment.

A convenient distinction is made between hallucinations and illusions. Hallucinations are defined as appearances wholly due to fancy; illusions, as misrepresentations of objects actually seen. There is, however, a hybrid case which deserves to be specifically classed, and arising in this way: Vision, or any other sensation, may, as already stated, be a "direct" sensation excited in the ordinary way through the sense-organs, or it may be an "induced" sensation excited from within. We have, therefore, direct vision and induced vision, and either of these may be the ground of an illusion. So we have three cases to consider, and not two. There is simple hallucination, which depends on induced vision justly observed; there is simple illusion, which depends on direct vision fancifully observed; and there is the hybrid case of which I spoke, which depends on induced vision fancifully observed. The problems we have to consider are, on the one hand, those connected with induced vision, and, on the other hand, those connected with the interpretation of vision, whether the vision be direct or induced.

It is probable that much of what passes for hallucination proper belongs in reality to the hybrid case, being an illusive interpretation of some induced visual cloud or blur. I spoke of the ever-varying patterns in the field of view; these, under some slight functional change, might easily become more consciously present, and be interpreted into phantasmal appearances. Many cases, if space allowed, could be adduced to support this view.

I will begin, then, with illusions. What is the process by which they are established? There is no simpler way of understanding it than by trying, as children often do, to see "faces in the fire," and to carefully watch the way in which they are first caught. Let us call to mind at the same time the experience of past illnesses, when the listless gaze wandered over the patterns on the wall-paper and the shadows of the bed-curtains, and slowly evoked faces and figures that were not easily laid again. The process of making the faces is so rapid in health that it is difficult to analyze it without the recollection of what took place more slowly when we were weakened by illness. The first essential element in their construction is, I believe, the smallness of the area upon which the attention is directed at any instant, so that the eye has to move much before it has traveled over every part of the object toward which it is directed. It is as with a plow, that must travel many miles before the whole of a small field can be tilled, but with this important difference—the plow travels methodically up and down in parallel furrows; the eye wanders in devious curves, with abrupt bends, and the direction of its course at any instant depends on four causes: on the most convenient muscular motion in a general sense, on idiosyncrasy, on the mood, and on the associations current at

the moment. The effect of idiosyncrasy is excellently illustrated by the "Number forms," where we saw that a very special sharply defined track of mental vision was preferred by each individual who sees them. The influence of the mood of the moment is shown in the curves that characterize the various emotions, as the lank, drooping lines of grief, which make the weeping-willow so fit an emblem of it. In constructing fire-faces it seems to me that the eye in its wanderings follows a favorite course, and notices the points in the pictures at large that coincide with its course. It feels its way, easily diverted by associations based on what has just been noticed, and so, by the unconscious practice of a system of "trial and error," at last finds a track that will suit—one that is easy to follow, and that also makes a complete picture. The process is essentially the same as that of getting a clear idea from out of a confused multitude of facts. The fancy picture is dwelt upon, all that is incongruous with it becomes disregarded, while all deficiencies in it are supplied by the fantasy. These latest stages are easily represented after the fashion of a diorama. Three lanterns are made to converge on the same screen. The first throws an image of what the imagination will discard, the second of that which it will retain, the third of that which it will supply. Turn on the first and second, and the picture on the screen will be identical with that which fell on the retina. Shut off the first and turn on the third, and the picture will be identical with the illusion.

Visions, like dreams, are often mere patchworks built up of bits of recollections. The following is one of these:

When passing a shop in Tottenham Court Road, I went in to order a Dutch cheese, and the proprietor (a bullet-headed man whom I had never seen before) rolled a cheese on the marble slab of his counter, asking me if that one would do. I answered "Yes," left the shop, and thought no more of the incident. The following evening, on closing my eyes, I saw a head detached from the body rolling about slightly on a white surface. I recognized the face, but could not remember where I had seen it, and it was only after thinking about it for some time that I identified it as that of the cheesemonger who had sold me the cheese on the previous day. I may mention that I have often seen the man since, and that I found the vision I saw was exactly like him, although, if I had been asked to describe the man before I saw the vision, I should have been unable to do so.

Recollections need not be joined like mosaic-work; they may be blended, on the principle I described two years age, of making composite portraits. I showed that if two lanterns were converged upon the same screen, and the portrait of one person was put into one and that of another person into the other, the portraits being taken under similar aspects and states of light and shade, then on adjusting the two images eye to eye and mouth to mouth, and so superposing them as exactly as the conditions admitted, a new face will spring into existence. It will have a striking appearance of individuality, and will bear a family likeness to each of its constituents. I also showed that these

composite portraits admitted of being made photographically * from a large number of components. I suspect that the phantasmagoria may be due to blended memories; the number of possible combinations would be practically endless, and each combination would give a new face. There would thus be no limit to the dies in the coinage of the brain.

I have tried a modification of this process with but small success, which will at least illustrate a cause of the tendency in many cases to visualize grotesque forms. My object was to efface from a portrait that which was common among persons of the same race, and therefore too familiar to attract attention, and to leave whatever was peculiar in it. I proceeded on the following principle: We all know that the photographic negative is the converse (or nearly so) of the photographic positive, the one showing whites where the other shows blacks, and *vice versa*. Hence the superposition of a negative upon a positive transparency of the same portrait tends to create a uniform smudge. By superposing a negative transparency of a *composite* portrait on a positive of any one of the *individual* faces from which it was composed, all that is common to the group ought to be smudged out, and all that is personal and peculiar to that face ought to remain.

I have found that the peculiarities of visualization, such as the tendency to see Number-forms, and the still rarer tendency to associate color with sound, is strongly hereditary, and I should infer, what facts seem to confirm, that the tendency to be a seer of visions is equally so. Under these circumstances we should expect that it would be unequally developed in different races, and that a large natural gift of the visionary faculty might become characteristic not only of certain families, as among the second-sight seers of Scotland, but of certain races, as that of the gypsies.

It happens that the mere acts of fasting, of want of sleep, and of solitary musing, are severally conducive to visions. I have myself been told of cases in which persons accidentally long deprived of food became subject to them. One was of a pleasure-party driven out to sea, and not being able to reach the coast till nightfall, at a place where they got shelter but nothing to eat. They were mentally at ease and conscious of safety, but they were all troubled with visions, half dreams and half hallucinations. The cases of visions following protracted wakefulness are well known, and I also have collected a few. As regards the effect of solitariness, it may be sufficient to allude to the recognized advantages of social amusements in the treatment of the insane. It follows that the spiritual discipline undergone for purposes of self-control and self-mortification has also the incidental effect of producing visions. It is to be expected that these should often bear a close relation to the prevalent subjects of thought, and,

* I have latterly much improved the process, and hope shortly to describe it elsewhere.

although they may be really no more than the products of one portion of the brain, which another portion of the same brain is engaged in contemplating, they often, through error, receive a religious sanction. This is notably the case among half-civilized races.

The number of great men who have been once, twice, or more frequently subject to hallucinations is considerable. A list, to which it would be easy to make large additions, is given by Brierre de Boismont ("Hallucinations," etc., 1862), from whom I translate the following account of the star of the first Napoleon, which he heard, second-hand, from General Rapp:

> In 1806, General Rapp, on his return from the siege of Dantzic, having occasion to speak to the Emperor, entered his study without being announced. He found him so absorbed that his entry was unperceived. The General, seeing the Emperor continue motionless, thought he might be ill, and purposely made a noise. Napoleon immediately roused himself, and without any preamble, seizing Rapp by the arm, said to him, pointing to the sky, "Look there, up there." The General remained silent, but, on being asked a second time, he answered that he perceived nothing. "What!" replied the Emperor, "you do not see it? It is my star, it is before you, brilliant"; then animating by degrees, he cried out, "It has never abandoned me, I see it on all great occasions, it commands me to go forward, and it is a constant sign of good fortune to me."

It appears that stars of this kind, so frequently spoken of in history, and so well known as a metaphor in language, are a common hallucination of the insane. Brierre de Boismont has a chapter on the stars of great men. I can not doubt that fantasies of this description were in some cases the basis of that firm belief in astrology which not a few persons of eminence formerly entertained.

The hallucinations of great men may be accounted for in part by their sharing a tendency which we have seen to be not uncommon in the human race, and which, if it happens to be natural to them, is liable to be developed in their overwrought brains by the isolation of their lives. A man in the position of the first Napoleon could have no intimate associates; a great philosopher who explores ways of thought far ahead of his contemporaries must have an inner world in which he passes long and solitary hours. Great men are also apt to have touches of madness; the ideas by which they are haunted, and to whose pursuit they devote themselves, and by which they rise to eminence, have much in common with the monomania of insanity. Striking instances of great visionaries may be mentioned, who had almost beyond doubt those very nervous seizures with which the tendency to hallucinations is intimately connected. To take a single instance, Socrates, whose *daimon* was an audible not a visual appearance, was subject to what admits of hardly any other interpretation than cataleptic seizure, standing all night through in a rigid attitude.

It is remarkable how largely the visionary temperament has manifested itself in certain periods of history and epochs of national life.

My interpretation of the matter, to a certain extent, is this: That the visionary tendency is much more common among sane people than is generally suspected. In early life, it seems to be a hard lesson to an imaginative child to distinguish between the real and visionary world. If the fantasies are habitually laughed at, the power of distinguishing them becomes at length learned; any incongruity or nonconformity is noted, the vision is found out and discredited, and is no further attended to. In this way the tendency to see them is blunted by repression. Therefore, when popular opinion is of a matter-of-fact kind, the seers of visions keep quiet; they do not like to be thought fanciful or mad, and they hide their experiences, which only come to light through inquiries such as these that I have been making. But let the tide of opinion change and grow favorable to supernaturalism, then the seers of visions come to the front. It is not that a faculty previously non-existent has been suddenly evoked, but one that had been long smothered is suddenly allowed expression and to develop, without safeguards, under the free exercise of it.—*Fortnightly Review.*

SCHOOL-ROOM VENTILATION.

By P. J. HIGGINS, M. D.

VENTILATION is the supply of fresh air to an apartment, and the removal of impure or vitiated air therefrom. An adequate supply of free oxygen is absolutely necessary to animal life; and, the higher we ascend in the scale of that life, the greater the quantity of oxygen consumed, and the more urgent the necessity for its consumption. In the atmosphere this oxygen exists in a free state—in mechanical solution—and in the form and proportion in which it is most easily assimilable. From the atmosphere, the animal absorbs it by means of its breathing apparatus which provides for its absorption by the blood, and the blood carries it to the tissues. *Pure air* consists of a mechanical mixture of about four fifths nitrogen and one fifth oxygen, with traces of ammonia, and about one part in two thousand of carbonic-acid gas (CO_2). These latter (ammonia and CO_2), from their small amount, may be neglected.

Air becomes vitiated for breathing purposes by holding in solution other gases or substances whose presence interferes with the appropriation of oxygen by the animal, or, being themselves absorbed, exert a toxic influence upon the vital fluid and tissues of the body. Hence to secure an adequate supply of fresh air, and the removal of impurities that accumulate therein, are the objects of ventilation. In this paper school-room ventilation only will be considered.

A full-grown person breathes on an average about twenty times

per minute, and takes in over twenty cubic inches of air at each inspiration. Boys and girls inspire somewhat less than twenty cubic inches, but breathe more rapidly than an adult—say twenty-five times per minute. In five minutes each will breathe over a cubic foot of air, and in a two-hours session nearly twenty-five cubic feet: so that, in a school of forty pupils, one thousand cubic feet will be inhaled every two hours. This is under, rather than above, the average.

Oxygen to the amount of nearly five per cent. of the quantity inhaled disappears at every breath, being absorbed by the blood—or twenty cubic inches per minute, for each individual—representing a total of fifty cubic feet for a school of forty pupils during a two-hours session. But, in addition to the consumption of oxygen, the air is further deteriorated by the exhalation of nearly as much carbonic-acid gas (CO_2) as there is oxygen consumed—say forty-five cubic feet in two hours, about one fortieth of the total amount produced being thrown off by the cutaneous surface of the body. Each cubic foot of carbonic-acid gas contains nearly half an ounce of pure carbon, or twenty-three ounces in all: so that, by breathing, forty mouths—like veritable little chimneys—puff out in two hours an amount equal to about a pound and a half of solid carbon. This is injurious in two ways, each of which will be examined in the proper place.

The air occasionally contains many impurities, but only those usually found in the school-room will here be enumerated. They are carbonic oxide (CO), carbonic-acid gas (CO_2), ammonia (NH_3), sulphur (S), sulphuretted hydrogen (H_2S)—all in the gaseous form; to which must be added aqueous vapor, organic matters, inorganic matters, epithelial cells, and animal exhalations.

The most toxic of all these is undoubtedly carbon monoxide (CO). It is a product of the incomplete combustion of carbon (C), but happily it is not usually found in the school-room in any large amount. A fire is the result of the chemical combination of the carbon of coal, or other combustible, with the oxygen (O) of the air; the atoms of the gas rush into combination with those of the carbon, and the arrested motion is transformed into heat—aqueous vapor (H_2O), carbon monoxide (CO), and carbonic-acid gas (CO_2), being produced. If a sufficient supply of air has free access to the *lower* portions of the fire, carbonic-acid gas is directly formed; but this in its passage upward through the central portion of the fire, where the temperature is higher, takes up another atom of carbon ($CO_2+C=CO+CO$) and becomes carbon monoxide, or carbonic oxide, as it is commonly called. This carbonic oxide, on reaching the upper surface of the fire, takes up an additional atom of oxygen from the air, and, burning with a bluish flame, becomes carbonic-acid gas once more, and makes its escape by the chimney. But usually a portion of the carbonic oxide fails to take up the additional atom of oxygen; and, when the supply of air is limited, the amount is increased, so that more or less car-

bonic oxide passes up the chimney along with the other gases of combustion. As the products of combustion are much lighter than the surrounding atmosphere—volume for volume—on account of their much higher temperature, and as the expansibility of gases is very great, they exert a pressure upon the sides of the pipe or flue through which they ascend. This being the case, these gases will escape through chinks, holes, or defective joints, along their course, like steam through a leaky conduit. Downward air-currents in the flue, and lateral currents from open windows, etc., occasionally blow large quantities of the gases of combustion through the open door of the stove, or through seams or cracks therein; and in these two ways—through stove and flue—sulphur, carbonic oxide, and carbonic-acid gas, may find their way into the room. It is claimed by some physicists that carbonic oxide will make its way through heated iron, and thus escape through the sides of the stove, but the quantity given out in this way—if, indeed, any is so given out, of which there is a reasonable doubt—must be so small that it is practically of no account, while quantities large enough to be decidedly injurious may issue through the door and other openings. Of course, these remarks apply only to schools heated by stoves; but it must not be forgotten that in rural districts, and many cities, all the schools are still heated in this way.

Carbonic oxide is a deadly poison, fixing itself in the blood-corpuscles and paralyzing them so that they can not carry on the function of respiration. To the inhalation of this gas is chiefly due the pale color of those who spend much time in apartments heated by stoves and poorly ventilated. Its presence can not be recognized by the senses, as it is tasteless, colorless, and inodorous.

Carbonic acid is produced in two ways, as before explained—by combustion and by breathing. The quantity thrown off in breathing is very much increased—often nearly doubled—during *active digestion*. As the fullest meal is taken at dinner, and digestion is most active soon after, it follows that the exhalation of carbonic-acid gas is greatest during the early part of the afternoon, and therefore during this time ventilation needs more attention. Of all the impurities found in the school-room, this is vastly the largest in amount, and popularly considered the most important. It is once and a half as heavy as air. At first sight, it might be supposed that, being heavier than air, it would sink to the floor and settle there in a layer of uniform height and density, like so much water. But this is not the case, for it is even more expansible than air. (Coefficient of expansion of air = ·00366; of CO_2 = ·00371.) Now, the law which governs the mixtures of gases is this:

The mixture of gases in free communication, whatever their density, takes place rapidly, and is homogeneous—that is, the mixture contains the gases in the same proportion; so that the percentage of carbonic-acid gas is about the same in all parts of the room.

If ample provision is not made for the removal of the vitiated air, the proportion of carbonic-acid gas continues to increase; and, as it is much heavier than air, the density becomes greater. Now, this increase of the air's density interferes with and retards the diffusion between the impure gases held in solution in the blood and the oxygen of the atmosphere—in other words, interferes with respiration. The consequence is, that the blood is not purified of the carbonic-acid gas which it holds in solution and combination. Not being removed as fast as it is formed in the body, it accumulates in the blood; the blood carries it throughout the system, circulating it through the delicate tissues of the brain. As the brain is the organ of the mind, it is by and through the brain that we think, reason, memorize, learn. For its healthy and vigorous action, a full supply of pure blood is an imperious necessity. The effects produced by this gas, when circulating through the brain in excess, are drowsiness, dizziness, dull headache, an inability to fix the attention, a dislike for application, a weakening of the memory, and a general torpor of the intellectual powers. An explanation of how and why these effects are produced would involve certain principles of mental physiology—a subject not within the scope of this paper.

Special attention is requested to this statement by Dr. Routh:* "Experiment has shown that if an animal be kept confined in a narrow, closed apartment, so that the air supplied is always more or less vitiated by the carbonic acid which it expires, however well fed that animal may be, tubercle (consumption) will be developed in about three months." If this be the case, a large percentage of cases of consumption should be met with among the inmates of badly ventilated schools. But, fortunately, the disease is comparatively infrequent under the age of fifteen, and added to this is the protecting influence of the active exercise in the open air usually indulged in by school-children. It is upon the teachers that its blighting effects are most apparent, as they are predisposed by age, they neglect exercise in the open air, and *their mental labor is severe, and worry of mind exhausting.* Of eleven teachers who died during the last eight years within the limits of one county in Pennsylvania, two died of acute disease, one of an overdose of an habitual narcotic, and of nine attacked by consumption, eight died—six ladies and one gentleman; the other, a gentleman, will recover, at least for a time.

The organic matters suspended in the air are derived (*a*) from the body; (*b*) from other sources. Epithelial cells or scales, very minute, arise by desquamation from the external cutaneous surface, and also from the mouth, pharynx, and bronchi. Being exceedingly light, they float in the air, and are inhaled, lodging in the throat, trachea, and even deep in the lungs. It is not pleasant to contemplate the fact that

*"Infant Feeding," Part IV, chapter iv.

we inhale minute portions of each other's bodies, but it is true nevertheless. In diphtheria, scarlatina, small-pox, measles, etc., these epithelial scales come off in vastly greater quantities than in health, carrying with them, in greater or less virulence, the peculiar infection in the body whence they have arisen. The greater their number and the more favorable the nidus in which they become deposited, the more likely they are to become transplanted as primary centers of infection. Hence it is important to prevent their *accumulation*, as the greater their numbers the greater the probability of their successful transplantation; and as they float in the air they follow its currents, and are thus removed by ventilation. Other sources of organic matters are various and numerous, but, with the following exception, of little importance in the present connection.

The cutaneous surface and the lungs give out certain odors, *sui generis*, which are designated "animal exhalations." It is to these that the heavy, sickening smell noticed on first entering a crowded room is due. Odors being volatile and exceedingly light, these exhalations rise to the highest portions of the room; and, if not allowed to escape, accumulate there, saturating the air from above downward, and finally reaching the floor. Of all the noxious matters in the fouled air of a poorly ventilated school or public building, these are at once the most perceptible, the most offensive, and the most rapidly prostrating. They produce a sensation of stifling by their irritation of the branches of the pneumogastric nerve distributed to the lungs and larynx, and nauseate, probably by reflex action, through branches of the same nerve distributed to the stomach. A distinguished physician, writing of an infant nursery under his charge where the children did not thrive, and many died of diseases of the digestive organs, says: "One remarkable circumstance observed was that there was a faint odor always present in the room. Yet it was a large room, about fifty feet in length. One side of the room was made up of windows which went up about ten feet where the roof or ceiling beveled up in an inverted $\wedge$ shape, which raised the room in the center seven or eight feet more. Do what I would, I could not get rid of this smell. One day, being much annoyed thereat, I procured some long steps which extended about three feet above the upper ledge of the windows. On walking up, no sooner had I got my head one foot above their level, than I found a terrible odor that made me feel giddy and sick; and I was glad enough to come down. I instantly sent for a workman, and desired him to remove three or four tiles at each end of the room, on a level with the highest point of the roof. He did so. In ten minutes all odor had disappeared; but his work was no sooner ended than he was taken very giddy and practically sick, so completely had he been overcome by the pestilential atmosphere." This incident will again be referred to in speaking of ventilators.

In regard to the moisture of the air, the following may be said:

The drier the air, the more rapidly are the liquids of the body evaporated, and digestion and assimilation carried on, the more nervous is the temperament, and the more rapid the development. Generally speaking, the air is much drier in the United States than in Europe. This is the chief reason why our children are less repressible, livelier, and more nervous and precocious than those of Europe. Another reason is, that we use here more animal food, which is far more stimulating both to body and mind than vegetable. On the other hand, too dry an atmosphere is unhealthy. As children drink much water, they exhale much aqueous vapor—the sweat-glands and capillary circulation being more active than in the adult—say to the amount of half a pint each, more or less, during school-hours. As such a large amount of invisible vapor arises, it serves a useful purpose by adding to the moisture of our dry air, rather than being injurious. In dwellings it is sometimes customary to place a vessel of water upon the stove to produce vapor, so as to diminish the dryness of the air; but, for the reason given above, it is perhaps unnecessary in a school-room. However, as water absorbs equal volumes of carbonic-acid gas, and four hundred and thirty volumes of ammonia, a shallow vessel of water may in this way be of some service.

The inorganic matters consist of chalk-dust, earth-dust, ashes, etc. Of late years, owing to the large amount of blackboard work done in schools, particularly in the primary departments, chalk-dust floats in large quantities in the air whenever the erasers are used. The particles of chalk-dust are comparatively large in size. When inhaled, it lodges in the posterior portion of the nasal passages and upper portion of the larynx; and when settled in large amount in these locations it gives rise to a good deal of irritation. The effect of this irritation is the secretion of a tenacious mucus that provokes distressing cough and unpleasant hawking. It is easy to understand how this exciting cause, long continued, may produce a chronic catarrh of these regions, especially in the posterior nasal passages, as they are prone to congestion and a low grade of chronic inflammation. The same remarks apply, but in a far less degree, to ash and earth-dust. The frequent cough and occasional sneeze heard among the audience in theatre, hall, or church, are provoked by the inhalation of fine dust suspended in the air, and might be prevented by careful sweeping and dusting after occupancy. The school-room should be swept every evening, and dusted at least an hour before opening. The blackboards should be erased as little as possible, and preferably by the so-called "dustless" erasers—though, strictly speaking, no eraser is really "dustless," being simply "less dusty"—and then gently in an up-and-down direction, so that the dust may not be dispersed through the room. The floor should not be disturbed by sweeping at any time during the day. Having examined briefly the different substances that vitiate or foul the air contained in a school-room, and the sources from which they

are derived, the means of effecting their removal therefrom will next be discussed.

The chief factors in carrying on ventilation are (*a*) the difference in temperature between the outside air and that within the room, and (*b*) the diffusibility of gases.

It is the difference *in temperature* that produces a draught up a flue or chimney when a fire is lighted below; for the products of combustion have a very much higher temperature (several hundred degrees Fahr.) than the surrounding atmosphere. Being so much warmer, they are lighter in consequence (as will be explained presently), and therefore have a constant tendency to ascend—being compelled by the force of gravity—till, after cooling little by little, they reach a layer of their own temperature. Upon the same principle an inflated balloon ascends and a cork immersed in water constantly tends to rise to the surface. As the coefficient of expansion for gases equals about $\frac{1}{273}$—i. e., they increase about $\frac{1}{273}$ of their bulk for every degree centigrade increase in temperature, *thus becoming lighter in proportion to their volume*, and, becoming lighter (some being originally lighter) than the atmosphere, are compelled by gravitation to ascend. It is important that the pipe or flue, in rooms heated by stoves or grates, should be vertical or nearly so; also that it be not too wide, otherwise downward currents will be produced, and these interfere with the draught, and cause the gases of combustion to escape into the room. In a stove-pipe the elbows should be as few in number as possible, and rounded rather than acute; for a sharp or abrupt bend materially diminishes the velocity of the draught. Two or more pipes opening into the same chimney should have *separate flues;* when they open into the same flue, the pipe that draws best will interfere with the draught in the others, and set up downward currents.

The air consumed by combustion escapes by the chimney, and tends to create a vacuum in the room; but it is steadily replaced by the atmosphere which rushes in at every available opening. This rush is strongest at the lowest openings (those nearest the earth), and here the whole amount enters if the space is sufficient. On the other hand, and for the reasons before given, the warmer (lighter) and fouled air within has a constant tendency to escape at the highest points; and it is here, therefore, that ventilators should be placed to allow its exit. Thus it is that, when a door is opened, the warmer (foul) air escapes in a current at the top, and the colder (fresh) from the outside rushes in at the bottom. This may be shown by a lighted taper held in these situations—the flame in each case taking the direction of the current. When the outside air is the warmer, and per consequence the lighter, as on a very warm summer day, the direction of the currents, other things being the same, will be reversed—the fresh air coming in above, and the cool air within escaping below. But, owing to the large amount of heat radiated from the pupils—the normal temperature of

the human body averaging 37·5° Cent., or 99° Fahr.—the lighter air is nearly always within. Therefore, if on the sheltered side a window is lowered at the top, or on any side if the air be calm, the foul air will escape above it; if raised from below, fresh air will enter beneath. But ordinarily it is sufficient to fully provide for the escape of the fouled air—the fresh, as a rule, will not need so much attention; yet it is better to make ample provision also for this. The best method is by ventilators in the walls—say of a foot square in section, or thereabout—raised but a few inches above the floor below, and lowered but a few inches below the ceiling above; or otherwise at the highest points of the ceiling itself. In this way the currents that are likely to blow on the children's shoulders when the windows are raised are avoided, a matter of importance; for a draught of cold air, blowing upon the shoulders *from behind*, arrests the action of the skin—probably through the spinal sensory nerves—and causes what is commonly known as a "cold." Even when windows are lowered at the top, draughts will occasionally blow upon the pupils; and, the lower the windows are set in the wall, the stronger and more uncomfortable and injurious is the draught. In order to prevent these draughts, the windows should be set high in the wall and lowered on the sheltered side whenever possible. An ingenious contrivance for the prevention of draughts through open windows has been suggested by Dr. Swinburne, in a paper read before the last annual meeting of the New York State Medical Society. It consists in the attachment of one end of a strip of unstarched muslin to a spring roller fastened to the casement above, and the other end to the upper edge of the window itself. On lowering the window, the muslin is unrolled, and thus stretches across the vacant space. Being held tense by the spring of the roller, it effectually shuts off all draught, while it allows the escape of the foul gases within, and the slow but steady entrance of fresh air.

Even should there be no currents through ventilators or open windows, yet the foul gases will make their escape by *diffusion;* for, according to the law of diffusion, there is a rapid interchange between gases in free communication. Of course, the outflow of the inside air very materially hastens the rapidity of the interchange; but the outflow will not, can not, be very rapid if there is not sufficient provision for the entrance of fresh air other than through the same apertures through which the outflow itself takes place. Again, the warmer the day, the less the difference between the temperature of the inside and the outside air; hence the buoyancy of the inside air is less, and consequently the ventilation not so effective; so that more attention and greater facilities must be afforded it. Ventilators should never be placed in the hall; here they do but little good. The doors leading from the hall to the rooms are usually closed, and, even if open, the buoyancy of the air as a factor in ventilation is nearly eliminated; for there is a partition between the hall and the room, so that the light

air and the lighter animal exhalations would be compelled to descend to the level of the top of the communicating door in order to escape. This they can not do, for it is in opposition to gravity. If no other outlet is provided, the only ventilation will be by diffusion through the doorway with the purer air in the hall. The animal exhalations will fill the room from the ceiling to the level of the top of the communicating door, and there remain. It would cost but a trifle to have one or two ventilators put in the ceiling of a school-room where there are none in the walls; and school directors could not make a better investment of the money. Children will not study, and can not be persuaded or compelled to study diligently, in the foul and stifling air of a crowded and wretchedly ventilated room. It may be safely asserted that in a majority of our schools the ventilation is insufficient, or not properly attended to, either on account of lack of knowledge or attention on the part of the teacher, or the defective construction of the building. A sanitary inspection should be made of every school in the State by a competent medical inspector; and all the schools found defective in this (or any other way injurious to health) should have all such defects remedied, or otherwise be condemned as unfit for school purposes, with the imposition of penalties for using them as such.

A school-room should have a high ceiling; contain from two hundred to three hundred cubic feet of air to each pupil; have one or more ventilators in the ceiling, or the walls near the ceiling; have long, high windows arranged to slide upward from beneath, and downward from above. All the children should be sent out at recess, if only for a short time, in order to have their clothing—saturated as it usually is by animal exhalations—exposed to the purifying influence of the open air, and doors and windows thrown open in order to completely change the air within. Stoves, chimneys, pipes, etc., should be carefully looked after, and any accident or defect promptly attended to, or immediately reported. Children convalescing from contagious diseases should be excluded from school for weeks, or months, according to the recognized limit of contagiousness of the disease. It should not be forgotten that the school and the church are the two great centers for the communication of contagious diseases; and that both are active in this way in direct proportion to the insufficiency of the ventilation.

ORIGIN AND USES OF ASPHALT.

By LEON MALO, C. E.

BITUMEN appears in nature as an accidental mineralogical product, under the most diverse and often most inexplicable conditions. It is found sometimes in the native state, sometimes mixed with clays, sometimes as the cement of conglomerates, sometimes im-

pregnating limestones. The last combination produces the mineral commonly called asphalt. When the bitumen contained in any of these substances is chemically isolated, it appears always a nearly identical substance, in composition, consistency, and appearance, except that the empyreumatic odor that characterizes it may become alliaceous in volcanic countries. Asphalt is doubtless one of the most considerable and valuable of the forms in which bitumen appears. It is a soft limestone, naturally and closely impregnated with that substance. When a specimen of it is examined under the microscope, each grain of it appears to be immersed in a pellicle of pure bitumen, by which it is cemented to the adjoining particles. It is thus a species of very fine-grained bituminous conglomerate. When a lump of this rock is heated to a temperature rising from 176° to 212°, the pellicle of bitumen is melted, the cohesion of the asphalt is destroyed, and it crumbles into dust. If it is taken while it is still hot, or if it is heated again after it has become cool, and strongly compressed, the particles will adhere again, and the stone will recover, after cooling, precisely the consistency and appearance it had originally. The employment of compressed asphalt for pavements is founded on this property.

Asphalt, or bituminous limestone, is generally found in the Jurassic strata, in regular beds of a lenticular shape, which are uniformly cut in two by a stream of water. Sometimes the bed is single, at other times it is multiple; there are formations containing seven beds, one above the other, and distinctly separated by strata of white limestone.

Different views prevail respecting the origin of asphalt and the circumstances under which it is formed. Some believe that the bitumen was already in existence when the calcareous formation took place, and that the particles of limestone were deposited in a bituminous sea. Others consider that the bituminous matter is derived from the organic matter associated with the shells that have furnished the carbonate of lime; and other more hazardous hypotheses have been advanced. A careful observation of asphaltic formations has led me to adopt what appears to me to be a more plausible theory.

It is permitted to suppose, from indications furnished by the study of bituminous districts, that in some geological epochs, which have yet been only imperfectly determined, accumulations of organic matter, buried under enormous masses of Jurassic limestone, and heated by the central fire, became vaporized, and in that condition sought a passage through the crust of the earth (Fig. 1). In time the crust cracked, and a fissure was formed. The bituminous vapors, compressed by incalculable pressure, forced themselves through the way that was opened to them, and passed by such strata as were too compact to be penetrated; but, when they reached the oölite, they found on either side of the fissure beds of a limestone soft enough to admit of their impregnating it (Fig. 2). As long as the pressure lasted, the bitumen con-

tinued to insinuate itself through the pores of the limestone, and to fill its infinitesimal cavities.

Mineral asphalt is relatively a soft stone. It becomes more compact as the temperature diminishes, but yields under the influence of

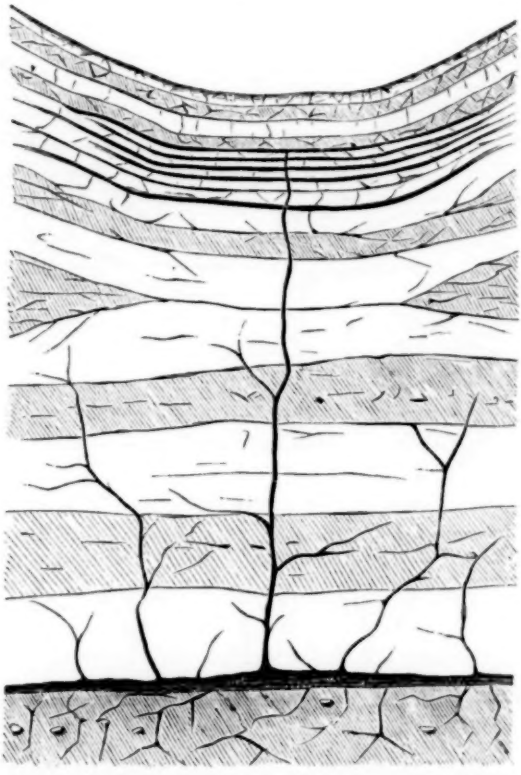


FIG. 1.—PROBABLE FORMATION OF ASPHALT BEFORE EROSION.

heat to such a degree that an exposure of a few days to the summer sun will sometimes cause it to crumble. This property has induced the application of the compressed material to the making of pavements. Its fitness for this purpose seems to have been suggested by accident. When the mineral was first quarried, the pieces which fell along the road from the wagons carrying it were ground up by the wheels, and were finally compressed again by the continued passage of the wagons over the dust, so as to form a kind of spontaneous pavement. A Swiss engineer, M. Mérian, acting upon the suggestion of this incident, asphalted a part of the road from Travers to Pontarlier, in a rough way, but with a satisfactory result. In the next year (1850), M. Darcy, inspector-general of bridges and highways, recommended asphalt as a material for pavements in a report to the Minister of Public Works. The first asphaltic pavement was laid in Paris in 1854.

The mineral appears in industry, under a still more useful form than the compressed form, as asphaltic mastic. This is made by throwing the powdered mineral into a bath of seven or eight per cent. of its weight of liquid bitumen, and mixing the whole thoroughly while it is cooked for five or six hours. The substance produced, although

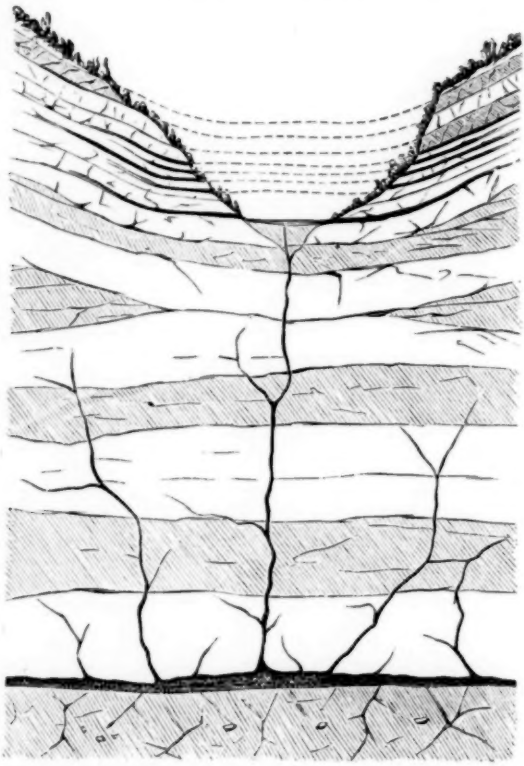


FIG. 2.—PROBABLE FORMATION OF ASPHALT AFTER EROSION.

chemically the same, except for the difference in the relative proportions of bitumen and limestone, is physically entirely different from asphalt. It can not be pulverized by heating, but forms a paste in which the two ingredients seem to be perfectly combined, and which may be molded into desired forms. The manufacture of the mastic has become an important industry. The annual production of the French shops alone must amount to fifteen or twenty thousand tons.

In "La Nature," of April 9th, Mr. A. Woeikofen, of St. Petersburg, describes the asphaltic beds of Russia, which occur on the grand curve of the Volga, or the arc of Samara, a short distance above the city of Syzran. They are not deposited in the Jurassic formation, as are those in France, Switzerland, and Germany, but in a dolomitic limestone of the lower Carboniferous series. The mineral is rich in bitumen, of

less fusible quality than the bitumens of France and Switzerland, and has not been produced in the compressed form. It is extensively made into mastic, the fabrication of which already amounts to ten thousand tons a year, and is rapidly increasing.—*La Nature.*

THE UNIT IN PLANT-LIFE.

By BYRON D. HALSTED, Sc. D.

MAN, being himself distinctly individualized, endeavors to find the unit of existence in all other forms of life. He meets with no great difficulties among the higher animals, but is perplexed and sometimes discouraged when search is made for the individual in the lower animals and in plants.

A child is an easily-recognized unit of life at its birth, and is no more than a single individual when it has reached mature middle life, or the decline and decay of old age. A limb may have been lost on the field of battle, or an eye removed by a surgeon, but there is no replacement of the lost parts. The human individual may suffer division, but it is a mutilation, and not a multiplication of the living unit.

In some respects the seed of a plant is analogous to the young of the higher animals; it is the result of a sexual union and the starting-point of a continuation of the species. For these and other reasons the seed may be, and has been, called the unit of life in the higher plants. But what possibilities are contained within the coats of a single seed when the proper conditions for its growth and propagation are secured! When we look beyond the dry and inactive seed, which can be held upon the tip of the little finger, and note what it may produce; when we know that such a single seed has been the starting-point of a variety of fruit that now has its representatives as full-grown trees in thousands of orchards all through this broad land, we must either expand our idea of a plant-unit until it is too great and comprehensive to be of service, or seek some other basis of individuality than that which is in some respects analogous to the accepted one among the higher animals. The idea of the identity of the individual among the more complex and perfect forms of existence in the two kingdoms of life may be dismissed, because the methods of propagation in the two are far from the same.

If we take some common plant of the higher orders—any tree or shrub, or even a herb—it will be found, upon careful study of its structure, that there is an almost monotonous repetition of parts. It will also be observed that these parts may be grouped under three heads, to which the common names of *root*, *stem*, and *leaf* are applied. The root includes that portion of the plant, whether aërial or subter-

ranean, the young growing extremities of which are protected by a layer of tissue called the root-cap. The stem is the axis of the plant, and is the part which bears the leaves, and includes those peculiar growths, such as thorns, runners, tendrils, etc., which serve a special purpose in the plant economy. The leaf is a lateral outgrowth from the stem, and is usually a flat, green expansion, but may assume the form of scales, highly-colored and strangely-shaped floral parts, etc. The fact that the largest tree and the smallest herb are alike made up of a greater or less number of *these plant-members*, as they are termed, leads naturally to the thought that any mass of plant-tissue having a root, a stem, and a leaf, may be a plant individual, and that, when a number of these members are intimately associated together, a *community* of plant individuals is formed. This is the modern conception of a tree or shrub—a living structure, which is the result of the combined, harmonious, silent working of many generations of individuals. Out of the three members are made all the multiplicity of forms and structures which meet our eyes as we look upon the higher forms of vegetation. They all have a common origin in the apical growing-points, and are indistinguishable in their earlier stages, but become differentiated as they develop, and at last assume their characteristic, mature forms. The growing-point of a stem (*punctum vegetationis*) is a conical apex, a little below which the leaves appear first as very slight swellings. By their more rapid growth than the stem, they reach above the growing-point, and, folding over each other, cover it more or less completely. As the stem elongates, the leaves upon the older portion are gradually separated, and an ordinary stem, with its leaves arranged at regular intervals, results. A bud is simply a young stem, with its undeveloped leaves. A developed stem is a series of similar parts, those parts being a leaf with a portion of the stem above and below it, each borne upon its predecessor, and in turn bearing the next one in the series. These similar parts have received the name *phyton*, and are very generally considered as the individuals out of which a plant community is built up. The gardener divides the young branches of the verbena, salvia, etc., into these phytons, and places them in moist sand, where they soon begin an independent existence, and in time reproduce their kind. In the operation of grafting, a similar portion of a plant community of one variety is given a fitting place for growth in another, and by its growth and multiplication of phytons a new colony is established. With this view a tree or shrub may form an *individual* part of a landscape, but not in the same sense that one may speak of a cow or a horse. The tree more nearly resembles a swarm of bees; there is a similarity of unity between a shrub and a hive. The larger part of the shrub is made up of foliar units, with ordinary leaves for the elaboration—gathering, so to speak, of the food for the whole community. These are the *workers* and the *neuters* of the vegetable "hive." Other plant

individuals devote their energies to the production of new plant-units, namely, the stamens—the male units of the flowers—which perish as soon as their transient but important work of fertilizing the pistil is accomplished; these are the *drones*. The pistil is the central part of the flower, and around which all the work of propagation converges and the labors of the year culminate, and from which the new individuals, the seeds, go forth to develop into free and independent colonies. In several respects this pistil is *queen* of the congregated vegetable units.

There are some objections to the phytons being considered the unit of vegetable life. The division of a plant may be carried beyond it, and life and growth of the parts still be maintained. Thus buds may arise from petioles, or leaf-stalks, and from the veins of the leaf, as in the ordinary propagation of the begonia, and very strikingly in the bryophyllum. Buds may start from the woody bundles of roots, as in the sweet-potato, poplar, or the cut stems of the elm, willow, etc. These many cases of a seemingly spontaneous growth have led to another definition of the plant-unit which is formulated briefly as follows: A plant individual is that smallest part that can grow when separated from its former place in a plant community, and given the fitting conditions for growth by itself. In most cases this "smallest part" is the phyton, or a portion of the stem with its leaf, and the bud or growing point which it bears in its axil. This young lateral bud, which is frequently so small as to be unseen by the naked eye, is, in fact, the vitalized, undeveloped stem that is to increase in size if growth takes place. The writer is of the belief that in this growing-point the individuality of higher plants should be located. If there are two buds upon the phyton, it seems proper to say there are two individuals, as there are two distinct points of growth, and two branches may result therefrom.

If the phyton is to be considered as the plant-unit, we must seek for another unit of life for those plants in which no phyton elements exist. The unit of growth is the cell; in it, either alone or in connection with other cells, all the functions of life are performed. Cells compose the growing tissue of every plant; in them resides that vitalized substance called protoplasm, in which all life-changes take place, and from which all structures are built up.

Many of the lower plants are unicellular, as, for example, the common yeast-plant, bacteria, etc., among fungi, and the desmids and diatoms among algæ. They increase in number by a simple division of the cell into two, each half increasing in size and dividing as did its parent. The individual among such plants is evidently the single cell. As we pass a little higher in the scale of vegetable life, it is found that though the cells are associated together in filaments, or laminæ, they are, in most respects, very independent, losing only a trifle of their originality by being associated in the simplest form of a com-

munity. As we pass upward in the scale, the differentiation increases, and there is a consequent division of labor, some of the cells being devoted to one kind of work, while others engage in a special labor for the community. Instead of the sum of the vital forces possessed by an individual being confined to a single cell, they are scattered through a large amount of growing tissue.

The seat of vitality is protoplasm, and wherever there is enough of this vitalized substance to grow and reproduce its kind, there we have an individual—a unit of life. It may be concentrated in a single cell, or distributed through many cells, the number and distribution being determined by the amount of dependence of the growing cells upon each other. The greater the division of labor, the higher the form of life, and the more difficult to recognize the individual; but, whenever it is found, it consists of a mass of protoplasm, usually contained in one or more cells, capable of growth under proper conditions, and ultimately reproducing its kind.

"THE ELECTRIC STORAGE OF ENERGY."

SOME few weeks ago a letter appeared in the "Times," signed "F. R. S.," describing a "box of lightning" which the writer had brought over from Paris for the purpose of submitting it to Sir William Thomson. Since then a long discussion has taken place on the subject of the invention and its usefulness. To begin with, we fully share the regret of Professor Tyndall, who has written a letter on the matter, that so much loose nomenclature has been introduced into the subject. The term "electric storage of energy" appears to us to be singularly unhappy. What is known as a condenser, or a Leyden-jar, is truly an instrument for the electric storage of energy, because, when charged, its parts are in a condition of molecular strain, which is recognized as an electrical phenomenon; and the release of this state of strain invariably produces at first some of the phenomena of electricity in motion. But in the case of M. Faure's secondary battery, which is the invention under discussion, although it is charged by a current of electricity and gives out a current of electricity, the form of the store of energy which it contains is not that of electrical stress or strain, but that of chemical separation—a form of potential energy which can be caused, under certain circumstances, to become kinetic energy in the form of heat. However, the term has now become established, and, being convenient, will probably survive. But it is to be hoped that the real state of things will be thoroughly and publicly explained by our leaders of science, so that the use of this form of words may not cause a confusion in scientific ideas.

From the ease with which secondary batteries can be constructed of very low resistance, so that they will give for a short time what practical electricians call a quantity current, they have been for some time in use for certain special purposes, principally for heating the wire of the galvanic *écraseur* in surgical practice. By a secondary battery is meant a galvanic battery which, as at first put together, has no tendency to give a current at all; but, if a current of electricity be passed through it of sufficient tension to decompose the fluids which it contains, will give a current in the opposite direction, due to the recombination of the separated parts of the decomposed fluid. The older forms consisted of two plates of platinum, preferably coated with spongy platinum immersed in a weak mixture of sulphuric acid and water, the action in this case being that the charging current decomposes the water (either directly or as the result of a chemical action set up by decomposing the acid first) into oxygen and hydrogen, which gases are absorbed by the platinum plates, the oxygen by one and the hydrogen by the other. When the charging battery is removed, the secondary battery will give a powerful current until all the oxygen and hydrogen absorbed by the plates are recombined in the form of water. It was afterward found that satisfactory results could be got from plates of lead treated in the same way. Their employment, of course, reduced the first cost of the apparatus. M. Planté then produced his secondary battery, in which he obtained great surface, and consequently low internal resistance, and large current, by rolling into a spiral form two lead plates separated by pieces of insulating material placed between them at intervals. He further succeeded in greatly increasing the time for which the battery would yield a given current, or its capacity, by adopting an elaborate process for the "formation" of the plates, which consisted in charging the battery and discharging it, varying the direction of the exciting current, and leaving the battery undisturbed between the charging and discharging for gradually increasing intervals of time. This process added enormously to the expense of the apparatus, which was also too bulky and heavy.

M. Faure, however, has succeeded in increasing the capacity of the battery, and getting rid of the long and delicate process of formation. His battery, like M. Planté's, consists of two plates of lead rolled together into a spiral, but he coats each plate with a thin layer of red-lead (one of the oxides of that metal), kept in its place by a piece of absorbent felt, which also keeps the two plates from touching. This felt is saturated with the weak acid. The effect of the exciting current in this case is to deposit spongy lead on one plate and to convert the red oxide on the other into puce-colored oxide which contains more oxygen than the red form; no doubt, also, the spongy lead at a late period of the charging becomes saturated with hydrogen. When the battery is now set in action, the spongy lead becomes reoxidized to red-lead and the puce-colored oxide reduced to the same sait.

Sir William Thomson early in this month wrote to the "Times," pointing out the great advance which this invention had made in the practical and economical storage of energy. His letter was answered by Professor Osborne Reynolds, who, with the intention of preventing the public from being astonished at the storing of so much energy as one million foot-pounds in apparatus occupying a cubic foot of space and weighing about seventy-two pounds, proceeded—somewhat irrelevantly as we think—to discuss the energy contained in a pound of coal, and also to complicate the now inevitable controversy by referring to a totally different problem, the transmission of energy by electrical means. The controversy thus started has gone on, Sir William Thomson, Professor Osborne Reynolds, Professor Ayrton, and Professor Tyndall, taking part in it.

The question, as far as the public are concerned, is a purely commercial one. As yet, of course, the data of the cost of the battery and its durability are not yet ascertained; but, in any future discussion on the subject, the question of convenience, as well as that of absolute expense, will have to be taken into consideration. At present we know that, at some expense, probably not too great, we can utilize a source of energy of feeble power for many purposes by allowing it to act for a long time, collecting its energy, and using it quickly, and that the loss in the process will be but small; and that, further, if it be desired to use the electric light temporarily, it can be produced conveniently, if not economically, by the use of M. Faure's invention. Sir William Thomson in his first letter points out many practical uses for the new invention; we may supplement them by pointing out how the new secondary battery may be applied conveniently for many purposes. Three ordinary Daniell's cells will charge an element of the new battery easily, so that, if there be plenty of time for preparation, we can, by the aid of Faure's batteries, use this cleanly apparatus, which gives off no noxious fumes and needs but little attention, for all the purposes for which, up to the present time, we were obliged to employ the costly and troublesome Grove's or Bunsen's batteries, which contain violent caustic poisons, and give off irritating and unwholesome fumes.

The whole discussion about the mechanical value of coal seems to us mistaken; neither Sir William Thomson nor any other physicist proposes to use the new battery universally, and, at present, our cheapest way of charging it is by the use of a dynamo-electric machine, driven by a steam- or gas-engine—i. e., by making use of the mechanical power of coal and the oxygen of the air; setting aside, of course, the exceptional cases where water-power is to be obtained. Sir William Thomson himself gave, we think, the *coup de grâce* to any attempt at comparing the relative values of transmitting electric currents through conductors from the source of energy to a distant station where energy is wanted, and conveying energy by exciting Faure's

batteries at the one place and conveying them to another, when he wrote in one of his letters of "Professor Reynolds's disappointment with M. Faure's practical realization of electric *storage*, because it does not provide a method of *porterage* superior to conduction through a wire." This is "like being disappointed with an invention of improvements in water-cans and water-reservoirs because the best that can be done in the way of movable water-cans and fixed water-reservoirs will never let the water-carrier supersede water-pipes wherever water-pipes can be laid." If we may venture to extend the great electrician's metaphor, it is like finding fault with the Great Eastern Railway Company's service of sea-water brought to London in cans, on the ground that it is just possible to obtain sea-water by a large main laid down to the coast, and that such a scheme is now under consideration. Another valuable property of the new battery is pointed out by Sir William Thomson. If it were to be used either at a fixed station to work an electric railway, such as the firm of Siemens have already brought into practical use, or to be carried on an ordinary carriage to drive it, the energy developed by the vehicle in running down-hill would be stored up ready to be used for its propulsion when it again reached a level or an ascending incline.

In the course of the correspondence Professor Ayrton has again mentioned the experiments which he and Professor Perry are carrying out with the view of using coal or coal-gas instead of zinc in a primary battery. Should he succeed in doing so, we should obtain a source of energy about ten times cheaper in working than the best-known steam-engine, and M. Faure's invention may very likely be the means of making it a commercial success; for, should Messrs. Ayrton and Perry, or any other physicist, succeed in making a coal or coal-gas battery giving a good proportion of the theoretical energy of the coal or gas, should it have a high internal resistance, it would be difficult to use it in practice; but, by the aid of Faure's batteries, in cases where work was only wanted to be done for a few hours a day, as in the case of electric lighting, the comparatively feeble current of the primary battery might be collected and stored for fifteen or sixteen hours, and then allowed to run out again in the eight or nine hours for which the source of energy is practically wanted.

The subject of this new secondary battery is one of great scientific importance. As the writer of a leader in the "Times" points out, it is by no means unlikely that a similar piece of apparatus may be made of some metal, and its appropriate salt, which shall be cheaper and lighter than one of M. Faure's form of similar powers; at all events, the invention and its results are pretty sure to turn the attention of inventors and investigators toward batteries both secondary and primary—a branch of inquiry which has for so many years been quite thrown aside in favor of endeavors to improve the dynamo-machine. Now, a primary battery is theoretically the most economical artificial source

of energy, and it is only the comparatively high cost of the fuel generally used in these—zinc—which prevents them from being practically useful. A galvanic battery gives out very nearly the whole energy due to the chemical combinations which take place in it; so that it is hardly too much to say that, were a battery to be employed to drive an electro-motor, under suitable conditions, we could obtain at least sixty per cent. of the chemical energy, while the best-known steam-engine will only give about ten per cent. of the chemical energy of the coal and air consumed in its furnace. There is thus a large margin for the first cost of the substance to be consumed in the battery.—*Saturday Review.*

SKETCH OF ROBERT WILHELM BUNSEN.

IT has been given to few scientific investigators to be more closely identified through their discoveries with the practical progress of the world, to see the fruits of their researches taken up and applied, made appreciable and beneficial in a greater diversity of lines, than to Robert Wilhelm Bunsen.

Professor Bunsen was born in Göttingen, March 31, 1811. His father was Professor of Theology, and of the Oriental Languages and Literature, in the University of Göttingen. Having passed through the course of the gymnasium, he entered the university, devoted himself to the study of chemistry and physics, and was graduated as a Doctor of Philosophy in 1830, publishing as his inaugural dissertation, "Enumeratio ac Descriptio Hygrometorum," or, "Enumeration and Description of Hygrometers." He afterward studied in London, Paris, and Vienna, and became, in 1833, tutor at the University of Göttingen; in 1836 he was appointed Professor of Chemistry at the Polytechnic school in Cassel; took the corresponding chair at the University of Marburg in 1838, and remained there thirteen years; then went, in 1851, to Breslau, where he planned a famous working laboratory; and in the next year went to Heidelberg, where he has for thirty years added to the fame of the great university.

His works in his chosen field have been numerous; their value, whether they are measured in relation to the advance of theoretical science, or as factors in the perfection of the operations of practical art, has been very great.

In 1834, in conjunction with Berthold, he published a research upon hydrated peroxide of iron as an antidote to arsenical poison, introducing a remedy which, having become universally known and universally accessible, may be regarded as a positive addition to the security of human life against a certain class of dangers.

He next, in 1835, described some singular compounds which the

double cyanides form with ammonia, and the crystals of many of the double cyanides. In 1837 he began a series of investigations of the liquid called Cadet's fuming arsenical liquid—the product of heating a mixture of acetate of potash and white arsenic, discovered in 1760—and brought out the radicle cacodyl, the first of a series of organo-metallic compounds which exhibit striking analogies with the metals. These bodies are unpleasant in every way, extremely poisonous, dangerously explosive, highly inflammable, and often, like cacodyl, insufferably offensive in odor. "It is difficult enough nowadays," says Professor Roscoe, in "Nature," "for a chemist to work with such substances, armed as he is with a knowledge of the danger which he has to encounter, as also with improved appliances of every kind to assist him in overcoming his difficulties. But Bunsen, forty years ago, was a traveler in an unknown and treacherous land, without sign-posts to guide him, or more assistance on his journey than was furnished by his own scientific acumen and his unfaltering determination. Nor did he escape scot-free from such a labor, for, in analyzing the cyanide of cacodyl, the combustion-tube exploded, Bunsen lost the sight of an eye, and for weeks lay between life and death, owing to the combined effects of the explosion and the poisonous nature of the vapor. 'This substance,' he writes, 'is extraordinarily poisonous, and for this reason its preparation and purification can only be carried on in the open air; indeed, under these circumstances, it is necessary for the operator to breathe through a long open tube so as to insure the inspiration of air free from impregnation with any trace of the vapor of this very volatile compound. If only a few grains of this substance be allowed to evaporate in a room at the ordinary temperature, the effect upon any one inspiring the air is that of sudden giddiness and insensibility, amounting to complete unconsciousness.'"

His next research, published in 1838, was into the chemical changes which occur in the blast-furnace. In it he showed that at least forty-two per cent. of the heat evolved from the fuel employed in the furnace was lost, and pointed out that a great economy might be effected by collecting the combustible gases which escaped, and saving them for subsequent use. The investigation led to the introduction of improved methods by which the waste gases were utilized, and the cost of the manufacture of iron was cheapened. The experiments made in this research were the first in which an accurate method of gas-analysis was employed, and entitle Bunsen to the credit of having introduced new and valuable processes in that line to chemistry.

In 1841 he invented the Bunsen battery, an apparatus which has come into general use as a scientific instrument, and in telegraphy. Its chief peculiarity is the substitution of carbon for copper or platinum as the negative pole.

He visited Iceland in 1846–'47, and devoted special attention to the study of the volcanic phenomena of the island, particularly of the

geysers. The memoirs which he published on the subjects of these studies contain the analyses of the volcanic rocks occurring in the island, which led him to the theory that all the eruptive rocks that reach the surface consist either of an acid or a basic silicate, or a mixture of the two, that has been formed and crystallized within the interior of the earth. Other papers relate to the formation of various crystalline minerals by the joint action of heat, acid gases, and moisture, on the rocks, and the theory of the geysers.

With the aid of his battery, Bunsen performed the electrolysis of some of the rarer metals. He began with magnesium, which he prevented from taking fire as soon as it came to the surface by the ingenious device of catching the metal as it rose in a cup, which he formed in his carbon pole for the purpose, while it was still under the salt. He then proceeded to the reduction, in conjunction with the late Dr. Matthiessen, of the alkaline-earth metals, and, with Hillebrand and Norton, of the metals of the cerium group. Applying metallic magnesium in photo-chemical researches and in comparison of the light of its flame with that of the sun, he gave the impulse which induced the undertaking of the commercial preparation of the metal.

Other researches, with which his name is connected, are those of Kolbe on the electrolysis of the fatty acids, of Kolbe and Frankland on the isolation of the organic radicals, the explanation of a new method of determining vapor densities, the investigation and correction of Dalton and Henry's law of absorption of gases in water, experiments on laws of gaseous diffusion, on applications of gaseous diffusion in gasometric analysis, on the phenomena of the combustion of gases, and on the temperature of ignition of gases; all of which were performed by himself or his pupils, or both.

In analytical chemistry Bunsen has contributed something valuable to the solution of nearly every important problem, and the best methods in complicated laboratory processes like those of the analysis of silicates and mineral waters, methods for the estimation of nitrogen and sulphur, and a method of volumetric analysis, which, though requiring considerable time for its completion, leaves little to be desired in point of accuracy and simplicity of manipulation. He introduced a general method for the separation of the rare earths, by which he for the first time prepared pure yttria and erbia, and by which several new metals have been discovered by other chemists.

In connection with his investigations on the measurements of the chemical action of light, Professor Roscoe, who was associated with him, speaks admiringly of his untiring energy and wonderful manipulative power, and says that, in all the difficulties and perplexities by which the experimental investigation of such a subject is beset, he never knew Bunsen discouraged, or at a loss for an expedient by which an obstacle could be overcome. "Cheerful and self-reliant under the most depressing circumstances, he never gave up hope, and thus it was

that these somewhat intricate and difficult investigations were brought to a successful close."

Perhaps none of his labors are more distinguished than the experiments with which he and Kirchhoff laid the foundation of the new science of spectrum analysis. Among his own most important transactions in this work was the discovery, by means of the spectrum lines, of the metals cæsium and rubidium. He first saw the cæsium lines, says Professor Roscoe, in a few milligrammes of the alkaline residue obtained in an analysis of the Dürkheim mineral waters, and the discovery of a second new metal (rubidium) soon followed that of the first. "So certain was he of the truth of his spectroscopic test, that he at once set to work to evaporate forty tons of the water, and with 16·5 grammes of the mixed chlorides of the two new metals which he thus obtained he separated the one metal from the other (no easy task) and worked out completely their chemical relationship and analogies; so much so, that the labors of subsequent experimenters have done little more than confirm and extend his observations." Another research in this direction was that on the spark spectra of the metals contained in cerite and other rare minerals, which he carefully mapped in such a manner as to make the separation and identification possible.

Bunsen's name is identified with two instruments which he has devised, which have come into general use in science and the arts; the Bunsen gas-burner, which is almost indispensable in laboratories and in many processes of manufacturing, and is used in many households; and the Bunsen pump for accelerating filtration, which those who employ it could likewise hardly do without.

His published writings are many. Most of them are special papers relating to the subjects of investigation that have been already mentioned; others embody more general results of his studies. His visit to Iceland gave rise to several papers on the various physical, geological, and volcanic phenomena of the island; his studies in metals to a number of monographs; his spectroscopic studies to "Chemical Analysis based on Observations of the Spectrum," published by him and Kirchhoff. Besides these, we may mention "Researches on Chemical Affinity"; "On a New Volumetric Method"; and "A Treatise on Gas Analysis."

Concluding his notice in "Nature," from which we have drawn liberally in the preparation of this article, Professor Roscoe says: "The many hundreds of pupils who, during the last half-century, have been benefited by personal contact with Bunsen will all agree that as a teacher he is without an equal. Those who enjoy his private friendship regard him with still warmer feelings of affectionate reverence. All feel that to have known Bunsen is to have known one of the truest and noblest-hearted of men."

CORRESPONDENCE.

THE PHENOMENA OF SPOUTING SPRINGS.

Messrs. Editors.

DEAR SIRS: On pages 28 and 29 of the May number of the "Monthly" there is given an explanation of the fact that some of the Saratoga springs spout intermittently, which seems to be entirely inadequate.

The author says: "As the water flows into the pocket from the surrounding inlets it gradually rises above the outlet, which results in the compression of the gas between the roof of the cavity and the surface of the accumulating water; when the force of compression reaches its maximum, it drives the water from the chamber up through the tube, from which it escapes in some instances to a distance of thirty feet in a vertical direction. After the pent-up water and gas have escaped, the spouting ceases," etc. There is nothing in the explanation or the diagram referred to in connection with it that would warrant the conclusion that gas thus pent up would relieve itself of pressure with a suddenness sufficient to produce the spouting. On the contrary, the flow of the spring, under the conditions stated, ought to be very uniform instead of intermittent. If the inflowing water "gradually rises above the outlet," the gas in the upper portion of the pocket would be as gradually compressed, and its reaction upon the water would tend, precisely like that of the air in the air-chamber of the common force-pump, to steady the outflowing stream and to prevent spouting.

Very respectfully,

G. H. COLTON.

HIRAM, OHIO, *May* 9, 1881.

CONTROL OF PAIN BY MECHANICAL VIBRATIONS.

Messrs. Editors.

As the article entitled "Mechanical Vibration as a Remedy in Neuralgia," in the Miscellany Department of the June number of "The Popular Science Monthly," is likely to elicit further inquiry, on account of the wellnigh universal interest in the conclusions set forth, I may be pardoned for offering a few facts pertinent to the same subject.

The control of neuralgia, and indeed of pain in almost any chronic form, by mechanical vibration, as asserted by M. Boudet de Paris and Dr. Granville, has been so thoroughly demonstrated as no longer to admit of question, and should be considered as well settled as any principle in medicine. Nor is the control of this agent over the nerves limited to pathological conditions. It is an anæsthetic as powerful as simple. Under its influence I have repeatedly witnessed such injury to the skin and flesh as would ordinarily produce unbearable pain, without in the least affecting the consciousness of the subject of the experiment. Indeed, so complete may the anæsthetic effect be made, that I have no doubt, were it possible to secure other mechanical conditions necessary, the capital operations of surgery might be painlessly performed under its influence. The same agent is also efficacious in removing obstinate insomnia.

The essential facts presented by M. Boudet de Paris and Dr. Granville, especially those relating to therapeutics, were given by the writer in considerable detail, in the "New York Medical Journal" (Appletons'), about ten years ago. These were then presented as the result of several years of experimenting with the agency in question, to determine the forms of apparatus required (which was found to admit of considerable variety, providing only that due rapidity of motion and shortness of stroke were preserved), and the efforts of varied methods of application in different pathological conditions of the nervous system. These articles were afterward published in book form, entitled "Paralysis and other Affections of the Nerves, and their Cure by Transmitted Energy."

The hypothesis of M. Boudet de Paris, that abnormal vibrations of the neuralgic nerve are opposed and annulled by mechanical vibrations, seems to imply a fixed rate for each of the differing conditions. In practice, it is found that the removal of pain is progressive, and the anæsthetic effect increases with increase of rate of mechanical vibration — which appears unfavorable to this hypothesis.

The efficacy of mechanical vibration to abolish pain may probably be explained on physiological grounds easily understood by all. For the application of this agent is in reality a supply of energy, which is immediately transformed into and merges with preëxisting physical operations of the vital system—of course, aiding to perfect these actions. No portion of such transmitted energy is lost—it only changes its form—and reappears in increase of temperature,

in motion of contents of obstructed capillaries, and a general rise of all physical operations to the normal degree. Congestion is as certainly removed as water from a sponge under pressure of the hand.

Among these intermediate effects of transmitted energy, the most certain and striking in a therapeutic view are *oxidation*, and what I will venture to call *functional revulsion*. The evidences of immediate and very great increase of oxidation in the living body superinduced by mechanical vibration are abundant and indisputable. The effect is, that the toxic principles incident to retained waste, in which the suffering nerves are bathed, are destroyed, certainly and quickly.

Functional revulsion is no less positive, and may be understood in this way. Like normal feeling, pain is entirely dependent for its existence on nutritive support; in fact, is *more* dependent. Such support during pain is, of course, excessive. To abolish pain, nothing more is required than to withdraw its support.

Now, the muscular masses entering into the composition of the body are, say, forty times that of the nervous masses; the latter are normally the incentives of the former to action, and therefore to nutrition. When nutritive action is incited in the combined mass, as it certainly is by mechanical vibration, it follows that the muscular portion receives the benefit overwhelmingly, both because of its immensely greater mass, and because it is *involuntary*. The function of the nerves, therefore pain, is suspended.

GEORGE H. TAYLOR, M. D.

EDITOR'S TABLE.

SELF-GOVERNMENT IN EDUCATION.

HE who said that the key to the government of mankind is given in the three words "hell and bayonets," made a compact formula for that system of external coercion by which human conduct in past times has been chiefly regulated. Men have been ruled through their fears and by intimidation, the state threatening the penalties of this world, and the Church those of the next, to enforce conformity to the prescribed standards of right conduct.

And there must be external compulsion, if there is no other. Men have to be dealt with according to their natures, and where these are low and brutalized they must be coerced by coarse and brutal methods. But social experience slowly develops the better traits of character, so that men become amenable to the influence of higher motives. In what we call the progress of society, external constraint gradually gives way and men learn more and more to govern themselves. Evolution here as elsewhere is by substitution. The progress of human freedom consists not in escape from restraint, but in the exchange of lower for higher restraints —in the replacement of state-control by self-control.

Unquestionably this is the most fundamental and important change that is going on in society. It is the highest aspect of human progress. It is the growth of the voluntary system, at the expense of the involuntary or compulsory. It is the development of mankind by discipline in the self-regulation of conduct. The transformation of men in this way is a great reality, and gives origin to whatever there is of free or liberal government in the world. All the humanizing influences by which men are ameliorated and improved take final effect in their liberation from external governing forces, so that they become responsible, self-determining agents, and in that sense free and independent.

How educational systems have been and are still related to this great tendency is a very interesting question. It can not be denied that they have had some share in promoting it, but their influence on the whole must be counted as powerfully adverse to it. In fact, school government has been generally modeled on the conception of monarchical government: the teacher has been

a "master," and has ruled his subjects by arbitrary coercion. The rod—the instrument of most degrading punishment—has ever been the symbol of educational control; and, although it begins to be widely seen that it does not represent the better method, thousands of schools are still fighting to maintain it. The schools reflect the general condition of thought, and, if the state is stringently coercive and the people tolerate it, the schools will imitate the policy. Besides, men love the exercise of power, and teachers are no exceptions to this dangerous propensity. External compulsion, moreover, is the simpler and easier way of governing, and, in fact, is all that is left to the teacher without resources. The resort to the rod and kindred measures stamps the teacher with incapacity for his vocation—that is, with an ability to govern by the best methods. Everybody knows that the rod plays no such important part in the work of education as it formerly played. Its sphere has been encroached upon by superior influences. Its stanchest defenders only claim to use it but "sparingly," and the best teachers reject it openly and entirely.

The old system is thus partially outgrown and much discredited; but there has as yet been but little intelligent and adequate effort to organize the method of self-government in its place. The more offensive forms of coercion are abated; but school-government still mainly rests upon external authority, though brought to bear in milder ways. There seems to be still but little recognition of the principle that the essential and supreme work of education is to form character by the cultivation of self-control, which implies liberty and responsibility. And this is not to be learned by precept, but by practice. Self-government, like music, can only be acquired by exercise, and to gain this the school itself must be worked by this method. Students must be thrown back upon themselves, and habituated to responsible self-direction.

As this is the highest result of education, so it is undoubtedly the most difficult of attainment. The grosser forms of punishment may be quite dispensed with, and still the school-goverment may be that of external caretaking and paternal regulation. The model college president has been the man who could know or divine everything that is going on among the students, and circumvent and disconcert them in all their little irregularities. Under this system it has ever been the ambition of the students to beat the faculty, and it naturally engenders a state of antagonism between the students and the governing authorities. Such a system by its very nature must fail to develop the most valuable traits of manhood.

From this general point of view we have taken much interest in the reform of collegiate government which has been attempted during the past year at Amherst. It is reported that President Seelye submitted a new plan to the faculty, that it was adopted, and that the results thus far have been in a high degree satisfactory.

The method consists in placing the student and the college upon an equal footing, and bringing them into relation by a mutual voluntary engagement. A correspondent of the "New York Evening Post" says:

> Every student upon entering college signs an agreement to observe its laws. This agreement is held to be a contract. If it is broken there is an end of the contract, and the contracting parties are as they were before it was formed. The student is no longer a member of the college, and the college owes nothing further to him. . . . The ground taken by the Amherst College government is that the faculty are the helpers of the younger men who want an education. The manhood of the students is recognized, and they are trusted to govern themselves without the interference of the faculty, save when the rupture of the contract compels the separation of a student from college.

At first the students did not grasp the sweeping force of the new laws, and one case of discipline, resulting, however, in a renewal of the broken contract by the student and college authorities, occurred before the idea was firmly fixed that the students were to be a self-governing body as far as their conduct is concerned, and that the only concern of the faculty was the observance of the contract and the retention of the students, or the end of contract relations with them if their promise should be broken.

Since this case, say the faculty, a higher tone has been observable among the students. They are no longer watched; professors do not feel called upon to act as police-officers; there is a freedom and self-accountability not known before, and consequently a better grade of deportment than before. After a student has been informed that he is no longer a member of college because he has broken his promise to obey the college laws, no further attention is paid to him. Should he come to recitations, as he can do, because they are open to visitors, he will be regarded exactly as a visitor. He can leave town or not, just as he chooses, and he can go to another college, as far as any notice from Amherst is to be feared. By the agreement among the colleges, no student could go from one to another without papers showing an honorable dismissal. No student expelled from one could find an open door at the other. Amherst has now withdrawn from that position.

President Seelye has made the following slight correction of the foregoing:

We have not yet relinquished the former prohibition upon the admission of students expelled from other colleges, nor are all who will sign the contract placed on an equal footing and no questions asked; on the contrary, no student is admitted here without a careful inquiry into his antecedents and his standing, nor unless he gives satisfactory evidence that his contract will be kept. We have only relinquished our claim upon the other colleges to help us by their prohibitions in maintaining our discipline.

We regard this experiment as having great significance. It is something to have this evidence of liberal aspiration on the part of college authorities, and it is much to have so prompt an acknowledgment of the salutary results of the reform; but everything is gained when such an institution steps forward and plants itself upon a great principle hitherto regarded as a mere matter of theory. It is more than a change in the form of government; it is an actual transfer of the governing power. Contracts are common things, and it may seem a small matter that a student should make a contract with the college where he proposes to be educated. But the contract is, that he is to govern himself, and voluntarily to square his conduct to the prescribed requirements of the institution. Honor, pride, ambition, are all pledged that he will keep his engagement. It is no small thing for a college quietly and effectually to secure these forces on the side of order, and thus avoid the conflict and antagonism with its students that coercive government naturally engenders; and it is certainly no small thing for the student to take a relation that will involve the constant and vigilant exercise of the most manly traits of character. The college thus becomes in an important sense a school of moral self-culture, a discipline in manhood, and offers the best preparation that can be given for the duties and responsibilities of practical life.

LITERARY NOTICES.

ANTHROPOLOGY: An Introduction to the Study of Man and Civilization. By EDWARD B. TYLOR, D. C. L., F. R. S. With Illustrations. New York: D. Appleton & Co. Pp. 448. Price, $2.

THE appearance of Mr. Tylor's long-expected manual of anthropology will be welcomed by many as a valuable contribution to the cause of advancing education. Anthropology, the science of man, is the latest and highest product of growing knowledge. Speculations concerning the nature of man began early, and were mixed up with the loose knowledge that gradually accumulated; but it is only in quite recent times that this knowledge has begun to be winnowed and sifted and verified and classified,

so as to take on something of the scientific form.

There has never been a lack of interest in the subject, and its claims and rank were neatly formulated by the poet, in his celebrated line—

"The proper study of mankind is man,"

long before the proper method of the study was discovered. Anthropological science—that is, the systematic and comprehensive study of the human race by scientific methods—belongs to the last half-century. A great amount of valuable knowledge has been accumulated upon the subject during that time, and digested in many voluminous treatises. But there was wanting a text-book that should sum up the leading facts and fundamental principles of the science in an authoritative and trustworthy manner, and in a form convenient and suitable for general use. Such a work is the one before us.

It need hardly be said that this is no field for the ordinary compiler. He may do useful service in the old sciences, where the subject-matter has been many times elaborated, and the method of exposition long settled; but only a master who knows his subject at first hand, broadly and thoroughly, can be trusted to present so vast a subject, and so rich in new and varied materials, in the due proportions of its parts, and in a compact, well-organized, and authentic form. Mr. Tylor, of all living men, was best prepared to accomplish this task. His elaborate works on "The Early History of Mankind" and on "Primitive Culture" have given him an eminent place as a pioneer and constructive student in the domain of anthropology. He has accordingly been long solicited to prepare a text-book upon this subject, for the use of students in high-schools and colleges, as it has been well understood that this science must soon take a leading and permanent place in the curriculum of a liberal education. The pressure of original studies prevented him from undertaking the work, and has much delayed it, but he has not allowed himself to be unduly hurried, well knowing the difficulty of giving his exposition a satisfactory form within the convenient limits of a handy-volume. But he has fulfilled the utmost expectations, and made his "Anthropology" the one unrivaled book upon that science for general educational purposes.

Of course, the scientific study of "Man and Civilization" can now be pursued only in the light of the doctrine of evolution. It is this law, indeed, that brings the facts of this subject into order, and gives organic method to the science. Anthropology is by no means a mere description of the different races and varieties of men; it deals also with the deeper problems of their transformation from lower to higher conditions, and with the development of all those elements which give rise to the civilized state. This is the underlying conception of the science, and how fundamental it is in the plan of Mr. Tylor's work may be best illustrated by briefly referring to the contents of his successive chapters.

In his first chapter, on "Man, Ancient and Modern," he opens up the new point of view from which man is to be studied. He then proceeds to define and fix the place of man in nature as related to other animals, considering the succession and descent of species, and the comparison of structure and brain endowments with inferior creatures. Chapter III is devoted to "The Races of Mankind," and is descriptive of their characteristics. The text is here illustrated by profuse and finely executed illustrations, of which we gave samples in the July "Monthly." The constitution, temperaments, types, permanence, mixture, and variation of races are here discussed, and the races of mankind are classified on the basis of these traits. The summary of the subject is admirable.

Chapters IV and V are devoted to "Language," which is of course considered as a problem of evolution. From the utterances of animals and the natural language of signs and gestures, and from emotional and imitative sounds, he proceeds to the origin of articulate language. The growth of meanings in articulate speech, abstract words, grammatical construction, and analytic and synthetic language, are then traced, with other important steps and elements of lingual development. Chapter VI, on "Language and Race," gives an account of the derivations and relationships of the languages used by different races; and Chap-

ter VII, on "Writing," takes up the subject of picture-writing, and the formation of alphabets.

Chapters VIII, IX, X, and XI, deal with the origin and development of the "Arts of Life," as shown in the construction of weapons, tools, machines, dwellings, clothing, in the means of navigation, in cookery and domestic processes, glass- and metal-working, money, and the operations of commerce.

Chapter XII delineates the origin and history of the "Arts of Pleasure," poetry, music, dancing, drama, painting, sculpture, and games; and Chapter XIII is an excellent monograph on the origin and growth of "Science."

In Chapter XIV, under the title of "The Spirit World," the religions of the lower races are taken up, and a description is given of the origin and influence of primitive ideas of souls, a future life, demons, gods, and worship. Chapter XV treats of "History and Mythology"; and Chapter XVI, which is the last, and entitled "Society," discusses the social stages, the family, property, justice, social ranks, and the growth of government.

It will be seen, from this brief synoptical view of the contents of his volume, that Mr. Tylor covers broad ground, but it will be found that the treatment of his topics is remarkably full and satisfactory. We cordially recommend his book to all students who desire to make a systematic study of man a part of their education, and we may add that the ordinary reader will find it full of interest and instruction.

ILLUSIONS: A PSYCHOLOGICAL STUDY. By JAMES SULLY. New York: D. Appleton & Co. Pp. 372. *International Scientific Series No. XXXIV.* Price, $1.50.

THE author of this work is now well known to the scholarly world by his original and comprehensive treatises on "Sensation and Intuition," and on "Pessimism." He is entirely familiar with modern philosophical problems, and has given critical attention to the bearings of science upon the class of questions that has interested him.

In the present volume he has taken up the subject of "Illusions" from a new point of view. Hitherto illusions have been commonly regarded as of the nature of mental aberrations or hallucinations, excluding the idea of sane intelligence. Illusions from this standpoint are allied to insanity, and their study is considered as belonging to the professional alienist or the physician occupied with mental derangements. There is, of course, abundant ground for this treatment of the subject, but Mr. Sully assumes that the subject has a far wider aspect, and can by no means be properly confined to the domain of pathology.

The author considers, on the other hand, that the liability to illusion is natural, and that it is but a part of that capacity for error which belongs essentially to rational human nature. All men err, some more habitually and more widely than others; but there are errors of illusion that belong to the normal operation of the human faculties, the study of which is quite as much related to the physiology as to the pathology of mind. It is therefore a legitimate problem of the psychologist who analyzes the conditions of sound and healthy mental action.

From this point of view the author remarks: "In the present volume an attempt will be made to work out the psychological side of the subject; that is to say, illusions will be viewed in their relation to the process of just and accurate perception. In the carrying out of this plan our principal attention will be given to the manifestations of the illusory impulse in normal life. At the same time, though no special acquaintance with the pathology of the subject will be laid claim to, frequent references will be be made to the illusions of the insane. Indeed, it will be found that the two groups of phenomena—the illusions of the normal and of the abnormal condition—are so similar, and pass into one another by such insensible gradations, that it is impossible to discuss the one apart from the other. The view of illusion which will be adopted in this work is that it constitutes a kind of border-land between perfectly sane and vigorous mental life and dementia."

Thus regarded, the study of illusions becomes properly a branch of logic; that is, it involves fundamentally the discrimination of that which is true from that which is false. The author at the outset makes a

definition and explanation which implies this idea. He says: "Taking this view of illusion, we may provisionally define it as any species of error which counterfeits the form of immediate, self-evident, or intuitive knowledge, whether as sense-perception or otherwise. Whenever a thing is believed on its own evidence and not as a conclusion from something else, and the thing then believed is demonstrably wrong, there is an illusion. The term would thus appear to cover all varieties of error which are not recognized as fallacies or false inferences. If for the present we roughly divide all our knowledge into the two regions of primary or intuitive, and secondary or inferential knowledge, we see that illusion is false or spurious knowledge of the first kind, fallacy false or spurious knowledge of the second kind. At the same time, it is to be remembered that this division is only a very rough one. As will appear in the course of our investigation, the same error may be called either a fallacy or an illusion, according as we are thinking of its original mode of production or of the form which it finally assumes; and a thorough-going psychological analysis of error may discover that these two classes are at bottom very similar."

It will be obvious that this is not a technical work, but one of wide popular interest, in the principles and results of which every one is concerned. The illusions of perception of the senses and of dreams are first considered, and then the author passes to the illusions of introspection, errors of insight, illusions of memory, and illusions of belief. The work is a noteworthy contribution to the original progress of thought, and may be relied upon as representing the present state of knowledge on the important subject to which it is devoted.

LITERARY STYLE AND OTHER ESSAYS. By WILLIAM MATHEWS, LL. D. Chicago: S. C. Griggs & Co. Pp. 345. Price, $1.50.

A MOST readable volume, full of common sense and practical wisdom on a great number of important and interesting subjects. The author is evidently an omnivorous and careful reader, and has well cultivated the art of turning his varied studies to good literary account. His pages are loaded, we might almost say overloaded, with references to the best writers, and quotations of their trenchant and suggestive sayings. The first paper, on "Literary Style," from which the volume takes its name, is not a scientific or philosophical analysis of the subject, but is a formidable array of arguments, illustrations, and authorities to prove that literary form is the main thing in the art of authorship. Dr. Mathews shows that, in literature, ideas, facts, and the substance of thought go for next to nothing, while the style of verbal dress determines the place and permanence of literary productions. The following passage on Carlyle will exemplify the fundamental idea of the essay, and illustrate also the author's lively and earnest style of discussion:

Perhaps no other writer of the day has more powerfully influenced the English-speaking race than Carlyle. Beyond all other living men he has, in certain important respects, shaped and colored the thought of his time. As an historian, he may be almost said to have revolutionized the French Revolution, so different is the picture which other writers have given us from that which blazes upon us under the lurid torch-light of his genius. To those who have read his great prose epic, it will be henceforth impossible to remember the scenes he has described through any other medium. As Helvellyn and Skiddaw are seen now only through the glamour of Wordsworth's genius—as Jura and Mont Blanc are transfigured, even to the tourist, by the magic of Byron and Coleridge—so to Carlyle's readers Danton and Robespierre, Mirabeau and Tinville, will be for ever what he has painted them. No other writer equals the great Scotchman in the Rembrandt-like lights and shadows of his style. While, as Mr. McCarthy says, he is endowed with a marvelous power of depicting stormy scenes and rugged, daring natures, yet, at times, strange, wild, piercing notes of the pathetic are heard through his fierce bursts of eloquence like the wail of a clarion thrilling beneath the blasts of a storm. His pages abound in pictures of human misery sadder than poet ever drew, more vivid and startling than artist ever painted. In his conflict with shams and quackeries he has dealt yeomen's blows, and made the bankrupt institutions of England ring with their own hollowness. What is the secret of his power? Is it the absolute *novelty* of his thoughts? In no great writer of equal power shall we find such an absolute dearth of new ideas. The gospel of noble manhood, which he so passionately preaches, is as old as Solomon. Its cardinal ideas have been echoed and reëchoed through the ages till they have become the stalest of truisms. That brains are the measure of worth; that duty, without reward, is the end of life;

that "work is worship"; that a quack is a Falsehood incarnate; that on a lie nothing can be built; that the victim of wrong suffers less than the wrong-doer; that man has a soul that cannot be satisfied with meats or drinks, fine palaces and millions of money, or stars and ribbons—this is the one single peal of bells upon which the seer of Chelsea has rung a succession of changes, with hardly a note of variation, for over half a century. Anything more musty or somniferous than these utterances, so far as their substance is concerned, can hardly be found outside of Blair's sermons. Coming from a common writer, they would induce a sleepiness which neither "poppy, mandragora, nor all the drowsy sirups of this world" could rival in producing. But preached in the strong, rugged words and with the tremendous emphasis of Carlyle: enforced by sensational contrasts and epic interrogations; made vivid by personification, apostrophe, hyperbole, and enlivened by pictorial illustration—these old saws, which are really the essence of all morality, instead of making us yawn, startle us like original and novel fancies.

The volume comprises upward of twenty essays, among which "The Duty of Praise," "A Plea for the Erring," "Hot-house Education," "The Art of Listening," and "Office-Seeking," are especially noteworthy.

THE BOLOMETER AND RADIANT ENERGY. By Professor S. P. LANGLEY. Reprinted from the "Proceedings of the American Academy of Arts and Sciences." Cambridge: University Press. Pp. 16.

THE BOLOMETER. By Professor S. P. LANGLEY, Allegheny Observatory, Pennsylvania. Read before the American Metrological Society, December, 1880. New York: Published by the Society. Pp. 7.

RECOGNIZING that the prism does not give the true values for the heat of the spectrum, and that it displaces the maximum ordinate of the heat-curve, the author has constructed and used a new apparatus—the "Bolometer," or "Actinic Balance," for the purpose of gaining a more actual value of the heat, the description of which and its operation is the chief purpose of these papers. With this instrument he has reached the interesting and unexpected conclusion that "the great proportion of all solar heat received at the earth's surface does not apparently lie in the non-luminous parts of the spectrum. Not only is the heat-maximum in the luminous part, but the total sum of non-luminous heat (so far at least as our measures extend) is relatively small."

SECOND GERMAN BOOK AFTER THE NATURAL OR PESTALOZZIAN METHOD FOR SCHOOLS AND HOME INSTRUCTION. By JAMES H. WORMAN, A. M., author of a Series for Modern Languages, etc., and Professor in the Adelphi Academy, Brooklyn, New York. New York and Chicago: A. S. Barnes & Co. Pp. 84. Price, 40 cents.

THE plan of the course of which this volume is a part has been developed during the practice of teaching German. Its general features are exclusive use of the German language without the help of the learner's vernacular; attention to grammatical and lexical details; the deduction of the rules from the examples; teaching by contrast and association; and graded lessons made up of conversations on familiar topics, so arranged as to supply a stock of words for daily use in common affairs.

REPORT ON FOREIGN LIFE-SAVING APPARATUS. By Lieutenant D. A. LYLE, Ordnance Department, U. S. A. Washington: Government Printing-Office. Pp. 48, with Nineteen Plates.

SEVERAL lots of foreign life-saving rockets were sent to Sandy Hook, New Jersey, in the spring of 1879, for examination and trial, under the inspection of the author. They were stored for several months under ordinary conditions of exposure, and then inspected and experimented with. The report describes the experiments and the results obtained with the Russian, German, English, and Hooper apparatus.

GEOLOGICAL SURVEY OF ALABAMA: REPORT OF PROGRESS FOR 1879 AND 1880. By EUGENE A. SMITH, Ph. D., State Geologist. Montgomery, Alabama: Allred & Beers, State Printers. Pp. 158, with Maps.

THE principal feature of the operations was the survey of the Black Warrior River and Warrior Coal Field, from Tuscaloosa to Sipsey Fork, conducted with a view partly to estimate the resources of the country, partly to ascertain the nature and extent of the obstructions to navigation, and the cost of removing or overcoming them. A report, by Henry McCalley, on the counties lying north of the Tennessee River is also included. Particular reports, with analysis, are given of fifty mines or outcrops of coal in the Warrior Field.

AMERICAN NERVOUSNESS, ITS CAUSES AND CONSEQUENCES. A Supplement to Nervous Exhaustion (Neurasthenia). By GEORGE M. BEARD, A. M., M. D. New York: G. P. Putnam's Sons. Pp. 352. Price, $1.50.

THE author believes that nervousness—"strictly, deficiency or lack of nerve-force"—is a modern affection, and that it is manifested in the United States through a variety of symptoms that are peculiar in many respects to the country, and remarkable. He ascribes its great development and rapid increase chiefly and primarily to modern civilization, which is different from the ancient civilization by a number of characteristics which breed mental activity and anxiety about time-tables, and excitements about matters of politics and business, for which the ancients had only a limited concern. It is aided by secondary and tertiary causes which might be comparatively unimportant in themselves alone, but which, combined with each other and with the chief cause, exert each its own kind and degree of effect. The symptoms by which this nervousness is manifested, numerous as they are, and unpleasantly as they often exhibit themselves, do not all betoken ill to the country; for brain-workers have in all ages been long-lived, longevity increases apace with nervousness; good taste, the beauty of women, the faculty of humor, the eloquence of oratory, increase with it; the evil of it tends, within certain limits, to correct itself; "and the physical future of the American people," says the author, "has a bright as well as a dark side; increasing wealth will bring increasing calm and repose; the friction of nervousness shall be diminished by various inventions; social customs shall be modified, and as a consequence strength and vigor shall be developed at the same time with, and by the side of, debility and nervousness."

THE LIBRARY. By ANDREW LANG. With a Chapter on Modern English Illustrated Books, by AUSTIN DOBSON. London: Macmillan & Co. Pp. 184. Price, $1.25.

THE purpose of this work is explained in its own pages thus: "There are, in every period of taste, books which, apart from their literary value, all collectors admit to possess, if not for themselves, then for others of the brotherhood, a peculiar preciousness. These books are esteemed for curiosity, for beauty of type, paper, binding, and illustrations, for some connection they may have with famous people of the past, or for their rarity. It is about these books, the method of preserving them, their enemies, the places in which to hunt for them, that the following pages are to treat."

THE MICROSCOPE AND ITS RELATION TO MEDICINE AND PHARMACY. Edited and published by CHARLES H. STOWELL, M. D., Assistant Professor of Physiology and Histology, University of Michigan, and LOUISA REED STOWELL, M. S., Assistant in Microscopical Botany, University of Michigan. An Illustrated Bimonthly Journal, Vol. I, No. 1. Ann Arbor, Michigan. Detroit: George S. Davis. Pp. 32. Price, $1 per year.

WHILE, in other medical journals that give attention to microscopy, microscopic topics are made secondary to medical ones, the conductors of this journal intend to give the most prominence to those subjects especially related to the microscope. The present number contains four original articles in the special department of the magazine, and presents matters of general interest to physicians and pharmacists, under the heading of "Editorial Abstracts."

PRINCIPAL CHARACTERS OF AMERICAN JURASSIC DINOSAURS. By Professor O. C. MARSH. Pp. 7, with Seven Plates.

THE discovery of a nearly complete skeleton of *Brontosaurus* has added many new points to our knowledge of the group of *Dinosauria*, some of which are given in the present paper. A second species, equally gigantic in size, has since been found, and two new genera from the same formation, all of which are noticed, and an outline of classification of the group is proposed.

INFORMATION FOR EMIGRANTS. THE CLIMATE, SOILS, TIMBERS, ETC., OF KENTUCKY, CONTRASTED WITH THOSE OF THE NORTHWEST. By JOHN R. PROCTER. Frankfort, Kentucky: Kentucky Geological Survey and Bureau of Immigration. Pp. 29.

THE Bureau of Immigration has already issued several publications setting forth the resources of Kentucky. Persons interested in the settlement of the Northwest have pub-

lished statements of the great advantages which that section offers to immigrants. The present tract is designed to exhibit the disadvantages of the Northwest, so as to prevent attention being turned away too much from Kentucky. The labor was not necessary. The advantages of Kentucky are too real and too well known to need exaltation through the depreciation of those of other parts of the Union.

INDUCTIVE METROLOGY. By W. J. McGEE. Pp. 8.

FOLLOWING up the suggestions of Mr. Petrie's English work on the "Recovery of Ancient Measures from the Monuments," the author insists on the necessity of more numerous and accurate measurements of the works of our American prehistoric races. The prevalent belief that the mound-builders used no unit of linear measure is contradicted by the measurements given by Messrs. Squier and Davis, by Mr. Petrie's deductions from them, and by the author's investigations. Computations made on these three bases nearly agree in giving a unit corresponding to 2·140 feet or 25·68 inches, with a possible error of ·0384.

NOSTRUMS IN THEIR RELATIONS TO THE PUBLIC HEALTH. By ALBERT B. PRESCOTT, M. D., F. C. S., Professor of Applied Chemistry in the University of Michigan. Pp. 12.

PROFESSOR PRESCOTT relates the results of the analyses made by himself and others of a considerable number of nostrums, which show that none of them contain anything new or rare, though many of them pretend to; that while many of them contain only what is at the best worthless, some contain substances that are actively injurious; that the composition of some is uncertain because it is often changed at the fancy of the proprietor; and that as a rule nostrums are better not used.

ON PHILADELPHITE (SP. NOV.). By HENRY CARVILL LEWIS. Pp. 16.

THIS paper is a description of a new mineral belonging to the vermicular group of hydrous silicates, occurring disseminated and in scales, and in seams in the hornblendic gneiss of parts of Philadelphia, which exhibits some remarkable properties.

ON THE GEOGRAPHICAL DISTRIBUTION OF THE INDIGENOUS PLANTS OF EUROPE AND THE NORTHEAST UNITED STATES. By JOSEPH F. JAMES. Cincinnati, Ohio. Pp. 17.

THE author believes that the species of plants common to Europe and America have had a common origin in the land about the north pole, and that they have migrated southward as the cold has increased in the Arctic regions; that on account of the present arrangement of isothermals some species reach in Europe a latitude higher by twenty degrees than that in which they are found in America; that the chain of the Rocky Mountains and the Andes furnishes or has furnished a highway for the dispersion of some Arctic forms over the southern hemisphere; and that the greater similarity between the floras of Europe, Northeast Asia, and Eastern America than between those of Asia and the American Pacific coast may be accounted for by reference to peculiarities of climatic conditions.

ANNUAL REPORT OF THE OPERATIONS OF THE UNITED STATES LIFE-SAVING SERVICE FOR THE FISCAL YEAR ENDING JUNE 30, 1880. Washington: Government Printing-Office. Pp. 391. With Plates.

THE record of the year covered by this report surpasses any previously made by the establishment. The service was distributed among 179 stations, of which 139 were on the Atlantic, 34 on the Lakes, and 6 on the Pacific. Three hundred disasters occurred within the scope of its operations, imperiling property to the value of $3,811,708, and the lives of 1,989 persons. Nineteen hundred and eighty of the men were saved, only nine being lost, and $2,619,807 worth of property were secured. The report gives the details of the operations and of the disasters.

THE SCHOOL OF LIFE. By WILLIAM ROUNSEVILLE ALGER. Boston: Roberts Brothers. Pp. 205. Price, $1.

AN essay, the scope of which is fairly described by the general subject of the title. It relates principally to the discipline and culture which we receive from our presence in the world and its action upon us, the use we should make of the opportunities it affords, and the methods by which we may attain the best-rounded manhood.

RAPID BREATHING AS A PAIN-OBTUNDER IN MINOR SURGERY, OBSTETRICS, AND THE GENERAL PRACTICE OF MEDICINE AND OF DENTISTRY. By W. G. A. BONWILL, D. D. S. Pp. 16.

THE author describes some experiments by which he has been led to assert that he can produce, from rapidly breathing common air, a similar effect to that from ether, chloroform, and nitrous oxide gas, in their primary stages, and can thus render patients sufficiently insensible to acute pain from any operation where the time consumed is not over twenty or thirty seconds. While the special senses are in partial action, the sense of pain is obtunded, and in many cases completely annulled, consciousness and general sensibility being preserved. He has used his method satisfactorily in his dental practice for four years, and refers to Dr. Hewson as having used it in obstetrics for three years.

GILL-NETS IN THE CODFISHERY: A Description of the Norwegian Cod-Nets, with Directions for their Use, and a History of their Introduction into the United States. By Captain J. W. COLLINS. Bulletin, U. S. Fish Commission, I. 1881. Pp. 17, with Nine Plates.

THE Fish Commission, believing the gill-nets to be a valuable fishing apparatus, has exerted itself to have them introduced and generally used in the United States. The present pamphlet is a part of its effort. The title furnishes a sufficient index to its reading contents. The plates exhibit the construction and method of setting and using the nets, to the minutest detail.

ANNUAL REPORT OF THE CHIEF-ENGINEER OF THE WATER DEPARTMENT OF THE CITY OF PHILADELPHIA FOR THE YEAR 1880. Presented to Councils, May 5, 1881. Philadelphia: John D. Avil & Co. Pp. 128.

A NOTEWORTHY feature of this report is that it seems to show that the water-power of the Schuylkill has been highly overrated, and has not half the value at which it has been estimated; hence attention should be diverted from water-power and turned to steam-power as a means of propelling the machinery by which a steady supply of water is to be secured from such works as those on which Philadelphia depends.

ANTIQUITIES OF NEW MEXICO AND ARIZONA. By W. J. HOFFMAN, M. D., U. S. A. Davenport, Iowa: Academy of Natural Sciences. Pp. 20, with Five Plates.

THIS monogram gives a tolerably full and very satisfactory description of the situation, construction, and present condition of the so-called ancient Pueblos, with notices of the potteries and other relics found in them, and some measurements of skulls. The figures in the plates are representations of numbered specimens in the National Museum.

POLITICAL ELOQUENCE IN GREECE: DEMOSTHENES. With Extracts from his Orations, and a Critical Discussion of the "Trial of the Crown." By L. BRÉDIF. Translated by M. J. MACMAHON, A. M. Chicago: S. C. Griggs & Co. Pp. 510. Price, $3.

A SERIES of essays on the life, surroundings, character, gifts, and public services of Demosthenes, and the general subject of "political eloquence in Greece." An analysis is given of the principal elements and characteristics of Demosthenes's eloquence.

PUBLICATIONS RECEIVED.

Ether-Death. By John B. Roberts, M. D. Philadelphia. 1881. 12 pages.

Catalogue of Exhibits at the Third Annual Reception of the Rochester Academy of Science. Rochester. 1881. Pp. 34.

The Saratoga Mineral Waters. Directions for their Use. By Dr. W. O. Stillman. New York: Taintor Brothers, Merrill & Co. 1881. Pp. 57. Illustrated.

Papers read before the Pi Eta Scientific Society, Rensselaer Polytechnic Institute, Troy, New York. 1881. Vol. II, No. 2. Pp. 101.

Studies from the Biological Laboratory of Johns Hopkins University. Edited by H. Newell Martin and W. K. Brooks. Vol. II, No. 1. 1881. Pp. 134. Illustrated.

On the Pathology and Treatment of Chorea, pp. 4; and Some Considerations on Insanity and its Therapeutics, pp. 7. By Edward C. Mann, M. D. New York. 1881.

The State and Higher Education. An Address before the Minnesota Academy of Natural Sciences. By Professor N. H. Winchell. Minneapolis., 1881. Pp. 18.

Objects of Sex and of Odor in Flowers. By Thomas Meehan. Philadelphia: "Gardener's Monthly" print. 1881. Pp. 3.

Anticipation of Lissajon's Curves. By Joseph Lovering. Pp. 7. With Plate. Large Telescopes. By Edward C. Pickering. Pp. 6. From "Proceedings of the American Academy of Arts and Sciences." 1881.

The New York Water-Supply. Report of Isaac Newton, Chief-Engineer, and Opinion of E. S. Chesbrough, Consulting Engineer. New York. 1881. Pp. 14.

The Solar Parallax as derived from the American Photographs of the Transit of Venus, December 8-9, 1874. By D. P. Todd, M. A. From "American Journal of Science," June, 1881. Pp. 3.

Brief Review of the Most Important Changes in the Industrial Applications of Chemistry within the Last Few Years. By J. W. Mallet, F. R. S. From "American Chemical Journal." Pp. 98.

Color-Blindness. Remarks by Dr. B. Joy Jeffries at the Twenty-ninth Annual Meeting of the Board of Supervising Inspectors of Steam-Vessels, January 25, 1881. Pp. 31.

Report of the Analytical and other Work done on Sorghum and Cornstalks by the Chemical Division of the Department of Agriculture, Peter Collier, Chemist. Washington: Government Printing-Office. 1881. Pp. 191. Twenty-seven Plates.

American College Directory and Universal Catalogue. Vol. III. 1881. St. Louis, Missouri: C. H. Evans & Co. Pp. 105.

Seedless Fruits. By E. Lewis Sturtevant, M. D. South Framingham, Massachusetts. Pp. 29.

Photometric Measurements of the Variable Stars β Persei and D. M. 81°.25. By Edward C. Pickering, Arthur Searle, and O. C. Wendell. From "Proceedings of the American Academy of Arts and Sciences." Cambridge. 1881. Pp. 27.

On the Action of Hyponitric Anhydride on Organic Bodies, pp. 13; and On the Production of Ozone by Heating Substances containing Oxygen. Pp. 5. By Albert R. Leeds. From "Journal of the American Chemical Society."

Fatal Form of Septicæmia in the Rabbit produced by the Subcutaneous Injection of Human Saliva. An Experimental Research. By Dr. George M. Sternberg, Surgeon United States Army. Baltimore. 1881. Pp. 22. Illustrated.

Transactions of the Seismological Society of Japan. Vol. I. Parts I and II, April–June. 1880. Printed at the Office of the "Japan Gazette." Pp. 116.

Discovery of Palæolithic Flint Instruments in Upper Egypt. By Professor Henry W. Haynes. From "Memoirs of American Academy of Arts and Sciences." 1881 Pp. 5. Seven Plates.

"The Magazine of Art," June, 1881. Cassell, Petter, Galpin & Co. London and New York.

Papers of the Archæological Institute of America. By A. F. Bandelier. Boston: A. Williams & Co. 1881. Pp. 133.

Ranthorpe. By G. H. Lewes. New York: William S. Gottsberger. 1881. Pp. 326. 75 cents.

The Emperor. A Romance. By Georg Ebers. From the German. By Clara Bell. 2 vols. New York: William S. Gottsberger. 1881. Per volume, 40 cents.

Rugby, Tennessee. By Thomas Hughes. London: Macmillan & Co. 1881. Pp. 168. $1.

A Theory of Gravitation, Heat, and Electricity. By Melville Marborg. Baltimore: John B. Piet. 1881. Pp. 104.

Sewer-Gas and its Dangers. By George Preston Brown. Chicago: Jansen, McClurg & Co. 1881. Pp. 242. $1.25.

Synopsis of the Fresh-Water Rhizopods. By Romyn Hitchcock. New York: published by the author. 1881. Pp. 56.

The Disposal of the Dead; a Plea for Cremation. By Edward J. Bermingham, M. D. New York: Bermingham & Co. 1881. Pp. 89. $2.

Osteology of Speotyto and Eremophila. By R. W. Shufeldt, Surgeon United States Army. Washington. 1881. Pp. 147. Illustrated.

Comparative New Testament. Old and New Versions arranged in Parallel Columns. Philadelphia: Porter & Coates. 1881. Pp. 690. $1.50.

A Text-Book on Anatomy, Physiology, and Hygiene. By J. T. Scovell. Terre Haute, Indiana, 1881. Pp. 88.

Butterflies; their Structure, Changes, and Life Histories. With Special Reference to American Forms. By Samuel H. Scudder. New York: Henry Holt & Co. 1881. $3.

POPULAR MISCELLANY.

Salmon of the Pacific Coast.—Messrs. David S. Jordan and Charles H. Gilbert, who have been engaged in the study of the fishes of the Pacific coast, state in the abstract of their report, which is published in the "American Naturalist," that they have observed five species of salmon (*Oncorhyncus*) in the waters of the North Pacific. These species may be called the quinnat or king-salmon, the blue-black salmon or red-fish, the silver salmon, the dog-salmon, and the hump-back salmon; and they are known by many other and vernacular names. The quinnat and blue-black salmon habitually *run* in the spring, the others in the fall, the two former species having the greater economic value. The spring-running salmon ascend only those rivers which are fed by the melting snows from the mountains, and which have sufficient volume to send their waters well out to sea, as the Sacramento, Rogue, Klamath, Columbia, and Frazer Rivers. They are chiefly adults, but their milt and spawn are no more developed in them when they go up the rivers than they are at the same time in others of the same species which will not enter the streams until fall. High water in any of these rivers in the spring is always followed by an increased run of fish, and it is believed that the disposition to run is excited by contact with cold water. The average weight of the quinnat in the spring is twenty-two pounds in the Columbia River, and about sixteen pounds in the Sacramento River. Individuals weighing from forty to sixty pounds are frequently found in both rivers, and some as heavy as eighty pounds. Fish that enter the rivers in the spring continue to ascend until death or spawning overtakes them. Probably none of them ever return to the ocean, and a large proportion fail to spawn. They are known to ascend the Sacramento to its extreme headwaters, about four hundred miles, and the Columbia as far as the Spokan Falls, a dis-

tance of between six and eight hundred miles. At these distances the bodies of the fish become covered with bruises, in which patches of white fungus are developed; their fins become mutilated, their eyes are often destroyed, parasitic worms gather in their gills, they become emaciated, the flesh becomes white from the loss of the oil, and they all die as soon as the spawning act is accomplished, often before. So far as has been observed, they are not known to feed after entering the rivers. The spawning-season varies in different rivers, and different parts of the same river, but not in the different species, and probably extends from July to December. In the spring the fish are silvery, spotted or not, according to the species, and have the mouth about equally symmetrical in both sexes. As the spawning-season approaches, the female loses her silvery color, and becomes more slimy, the scales on the back partly sink into the skin, and the flesh changes from a salmon-red to a paler color. As the season advances, the differences between the males and females become more marked, in proportion as the milt is developed. The difference in the economic value of the spring and fall salmon, which is vastly in favor of the former, is dependent on the fact that the spring salmon enter the rivers long before the growth of the organs of reproduction has reduced the richness of the flesh, while the fall salmon can not be taken in quantity until their flesh has deteriorated. The quinnat is more valuable, on account of its size and abundance, than all the other fishes on the Pacific coast together; and the blue-back is worth much more than the combined value of the three remaining species. "It is the prevailing impression," say the authors of the report, "that the salmon have some special instinct which leads them to return to spawn in the same spawning-grounds where they were originally hatched. We fail to find any evidence of this in the case of the Pacific coast salmon, and we do not believe it to be true. It seems more probable that the young salmon, hatched in any river, mostly remain in the ocean within a radius of twenty, thirty, or forty miles of its mouth. These, in their movements about in the ocean, may come into contact with the cold waters of their parent rivers, or perhaps of any other river, at a considerable distance from the shore. In the case of the quinnat and the blue-back, their "instinct" leads them to ascend these fresh waters, and, in a majority of cases, these waters will be those in which the fish in question were originally spawned. Later in the season the growth of the reproductive organs leads them to approach the shore and to search for fresh waters, and still the chances are that they may find the original stream. But undoubtedly many fall salmon ascend or try to ascend streams in which no salmon was ever hatched." The evidence is not clear whether salmon are diminishing in numbers or not, except in the Sacramento River, where they are undoubtedly decreasing.

Storage of Electricity.—The reproach against electricity that it can not be stored seems now to be in a fair way of being removed by M. Camille Faure's recent improvement of the Planté secondary battery. The cells of this battery, as is well known, consist simply of two lead plates immersed in acidulated water, one of which becomes oxidized by the passage of a current through the cell, and is reconverted into the metallic state when the charging current ceases, yielding a current while undergoing this latter transformation. Once charged, the battery may be kept a considerable length of time without losing its power, and gives out a current steadily in a manner similar to an ordinary voltaic cell. The Planté cell is, however, not of commercial value, as its capacity is small, and it requires a considerable time to charge it. These difficulties M. Faure appears to have largely overcome by simply coating the plates with minium or red-lead, whereby their chemical dissimilarity, and consequently the electrical capacity of the cell, is greatly increased. When the charging takes place, the minium upon one plate is further oxidized to the peroxide, and that upon the other reduced to the metallic state, a current being given out while these plates are assuming their original condition. The cell is stated to give eighty per cent. of the current used to charge it, and to retain its charge for a considerable period. A battery containing four cells, and of the size of a cubic foot, was recent-

ly sent from Paris to Sir William Thomson at Glasgow, which was found by him to contain electrical energy equal to something over one million foot-pounds, or one-horse power, for one hour. Though the battery was seventy-two hours reaching him, it was found to have lost but very little of its original charge, and he has since been able to detect but a slight loss in a period of ten days. The expectations regarding the uses to which this battery can be put are doubtless exaggerated, but it seems safe to predict for it a large field of usefulness. It can probably be employed to advantage, if further experiment bears out present statements regarding it, wherever ordinary batteries are used, as it possesses the convenience of these combined with the cheapness of the dynamo-machine in the matter of the currents furnished. In the electric-light it will probably find an important use in equalizing the currents of the machines, and preventing interruption of the light in case of a temporary failure of the generating apparatus. It is, moreover, not impossible that it may dispense with the need for electrical distribution at all, as such batteries placed in houses could be charged each day by small dynamo-machines driven by gas-engines, at but small expense and with the minimum amount of trouble.

Color-Blindness and Education of the Color-Sense.—The examinations instituted by Dr. B. Joy Jeffries among the pupils in the schools of Boston (including 14,469 boys and young men and 13,458 girls and young women) have shown that about one male person in twenty-five is color-blind, while the defect occurs with extreme rarity in girls and women (only 0·066 per cent. of the female pupils in the schools). The researches that have been made in Europe show that a similar law as to the relative proportion of color-blindness between the sexes prevails there. The subject has been overlooked until within a few years, but the value of the knowledge of it that has been gained can not be disputed. This knowledge can be applied practically on a scale of considerable extent in determining the vocation to which boys should be trained. A person who is color-blind is obviously unfit for any business in which he must know how to distinguish colors. Yet the person himself and those who are around him are seldom aware of his defect. If examinations are regularly made in the schools and records kept of them, as has been done by Professor Jeffries, a sure practical test may be found which can be applied directly to each person, so as to guide him aright on this point. The inquiries of Dr. Jeffries have disclosed a great lack of knowledge of colors, aside from color-blindness, among adults as well as among the boys in the schools. But very few boys of the grammar or higher schools, he says, are familiar with the color-names of even the primary colors, and still less can they correctly apply those names they do remember, when shown colored objects. "I have received letters from adults, not color-blind, whose lack of color-names had been a serious drawback to them in their occupations in every-day life; and they have besought me to urge the teaching of color-names and the education of the color-sense in our public schools." The teaching of colors and color-names has been partly introduced into our primary schools, but without any system; it has been begun in Europe, especially in Germany, in the lowest schools, in a systematic manner. The exemption of women from color-blindness has been attributed to their familiarity with colored objects and materials; but this holds only of the sex as a whole, not with reference to individuals, for the color-sense can not be changed with practice in colors. The question arises whether generations of color-education have caused this sexual difference, and is important; for, if answered in the affirmative, it proves that we may begin to eliminate color-blindness from future generations of boys by teaching and exercising the present generation in the perception and distinction of colors.

Climate and Health.—Mr. Alexander William Mitchinson has read an important paper in the Society of Arts on "The Principal Causes of Disease in Tropical Countries." It is usual to trace these causes back to the climate, but Mr. Mitchinson maintains that climate has less to do directly in producing disease than has generally been supposed. Every climate and country has its own appropriate and dietary laws, and

exacts obedience to them at the cost of sickness; but, when these laws are obeyed, the difference in the healthiness of climates becomes comparatively insignificant. Europeans going to tropical countries are apt to neglect the precautions with reference to food which the changed conditions of their life would require them to take, and, instead of reducing the quality and varying the nature of what they eat, too often grant themselves the indulgences of rich viands, with high seasonings and wines, which they enjoyed at home. The mistake is even made of increasing the quantity and richness of the food, under the impression that the exhaustion produced by the climate should be met in that way, while a lighter diet is what is really required. The stomach can not bear the burden imposed upon it, and symptoms of disease arise. The loss of memory and mental capacity, which have been remarked as effects of a long residence in the tropics, are partly due to tropical heat, but far more to the solitude, with insufficient variety of incident, and the want of mental exercise, to which residents are exposed by the lack of society and of the distractions which society promotes. "Europeans in Africa do little else than eat and drink, rest and sleep," will seek for nothing to occupy their minds, and will often sit listlessly for hours gazing at vacancy. Consequently the mind is apt, from want of judicious exercise, to sink gradually, and the man to fall into apathy. In such a condition he is far more liable to an attack of fever than one who has preserved his mind in a state of healthy vigor. Other mistakes committed by European residents, which almost surely lead to disease, are the excessive use of spirits—dangerous in the tropics above all other regions—carelessness in regard to exposure, and neglect of exercise. More or less of exposure to the atmospheric changes of the country is inevitable, and the body that is prepared to withstand them is in less danger from them than are the too sensitive organizations of those who take too much care of themselves. This preparation can be gained by judicious exercise at different periods of the day and year. The bad location, and neglect of the sanitary condition of the coast towns, are responsible for much of the unhealthiness which is associated with Africa. Many of them are built near marshes or lagoons, in the very worst places that could be selected, such as would be pestilential spots anywhere, and they have been suffered to grow up and accumulate nuisances without a thought of the application of sanitary science, which seems to be wholly unknown, to their improvement. The natives have an effectual means of warding off malaria by planting groves of trees between the swamps and their villages, or by burning the bush and allowing the soil exposed thereby to acquire a crust, which impedes the rising of the malarious vapors. "In the British possessions such obvious means of protection appear to be either unknown or despised." The rule of life Mr. Mitchinson would lay down for a resident in the tropics is based upon the words "diet, exercise, and energy." These, he says, are the man's climate, his life, the power of the intellect nourished by the normal blood. "The rule of life adopted by most Europeans in the tropics, so far as they can be said to have any rule, appears to be 'feed and rest, rest and feed"; few give any intelligent consideration to the subject of the preservation of health." It is no wonder, then, that European residents die early.

Movements and Mixtures of African Races.—Messrs. de Quatrefages and Hamy have presented an important paper on the craniology of the dolichocephalous negro races. These races occupy the most considerable part of the geographical area inhabited by the negro race on the African Continent. Regarded as a whole, they present a considerable homogeneity in the most essential characteristics; but differences of habitat and the mixture of foreign elements have caused their secondary characters, both exterior and anatomical, to vary within considerable limits. Consequently, they are divided into a considerable number of groups —groups which are increasing. The Soodanian group, which presents the most complete exemplification of the general type, occupies all the space comprised between the Sahara on the north, Senegambia on the west, Guinea on the south, and the valley of the upper Nile on the east. The Soodanians may be classified as eastern and western. The cranial capacity of the west-

ern Soodanians is probably inferior to that of all the other negro races of the same type, and exhibits a most pronounced dolicocephaly. The eastern Soodanians approach this type, but some of its most characteristic marks are less distinct in them. To them may be attached the negroes living on the banks of the upper Nile and the great lakes. Furthermore, a great variety is apparent among the races, and the ethnic mixtures are considerable. Africa is not, in fact, that stationary land which it is generally figured to be. It has, like the other continents, its grand movements of people and races. A current which is sometimes slow, sometimes more or less rapid, which seems to have existed for several centuries, is drawing the negro populations from the interior. Northeast of the Gulf of Guinea, toward the coast, the nature and importance of this movement, which is pushing the population from east to west, can be appreciated best at the Gaboon. There the Gaboonese first subjugated and absorbed the Negrilles, Akoas, and others; then the Bakales pushed them farther west; and the last are now pressed by the Fans, who are coming down from the interior. The Caffres are not a simple ethnic element, but are a mixture of negro and Bushman elements complicated with Arabian and even Malaysian elements. The Bushmen are the real indigenous race of Southern Africa; the Hottentots, the Koranas, the Gonaquas, and the Namaquas, are only hybrids of this race mixed in different degrees with the negro race.

Mr. Whymper's Experiments with "Mountain-Sickness."—Mr. Edward Whymper, in relating the story of his ascent of the mountains Chimborazo and Cotopaxi, has described the efforts which he made to counteract the "mountain-sickness" or sense of exhaustion and feverishness which attacks all persons who venture to great heights. Till his own attempt was made, he had not known of any traveler afflicted with the peculiar feeling who had deliberately "sat it out, and had a pitched battle with the enemy," or of any one who had suggested the bare possibility of coming out victorious from such an encounter, yet, upon doing so, he felt, depended the chance of pushing explorations into the highest regions of the earth, and he was anxious to test whether his organization could not accommodate itself to the required conditions. Only three well-authenticated instances were known of persons who had reached the height of twenty thousand feet, and their stories gave no light on the subject; but a person who had reached the height of between seventeen and eighteen thousand feet told him that, though he never had suffered from the affection, he could not escape it at such elevations. On the first day of his ascent of Chimborazo, he reached a height of 14,400 feet. On the next day he reached 16,500 feet, and established himself there with great difficulty. "The mules were forced up to the very last yard that they could go, and, staggering under their burdens, which were scarcely more than half the weight they were accustomed to carry, stopped repeatedly, and by their tremblings and falling on their knees, and general behavior, showed that they had been driven to the very verge of exhaustion." Within an hour Mr. Whymper and his Italian mountaineers, the Carrels, were lying on their backs, incapable of making the least exertion, feverish, with intense headaches, and unable to satisfy their desire for air, except by breathing with open mouths. "This naturally parched the throat, and produced a craving for drink which we were unable to satisfy, partly from the difficulty of obtaining it, and partly from the difficulty of swallowing it, for, when we got enough, we were unable to drink, we could only sip; and not to save our lives could we have taken a quarter of a pint at a draught. Before one tenth of it was down, we were obliged to stop for breath, and gasp again, until our throats were as dry as ever. Besides having our normal rate of breathing largely accelerated, we found it impossible to get along without every now and then giving a spasmodic gulp, just like fishes when taken out of the water. Of course, there was no desire to eat; but we wished to smoke; and even our pipes almost refused to burn, for they, like ourselves, wanted more oxygen." He obtained relief by taking chlorate of potash, and in two or three days the party had become accustomed to the situation, and were able to continue their work. The next camp was pitched at a height of 17,400 feet.

The more disagreeable symptoms had gone, but the mountaineers still found themselves "comparatively lifeless and feeble, with a strong disposition to sit down when we ought to have been moving." At length, having spent three days in moving their camp, and having passed a night at the highest station, they undertook the ascent to the summit. It was extremely difficult, made in the face of a high wind and through soft snow in which the men sunk to their necks, but it was accomplished, the measurement of the height was taken, and the return safely made to the camp, all in one day. The most notable physical experience of the ascent was the observation, at a height of between 18,400 and 19,500 feet, that "our steps got shorter and shorter, until at last the toe of one foot touched the heel of the previous one." Mr. Whymper's residence on Chimborazo "extended over seventeen days; one night was passed at a height of 13,400 feet, ten nights at a height of 16,500 feet, six at 17,300 feet. During this time, besides the ascent to the summit, I also went three times as high as 18,300 feet. When we quitted the mountain, all traces of mountain-sickness had disappeared, nor did it touch us again until we arrived at the summit of Cotopaxi." The camp on the latter mountain was placed about 130 feet below the loftiest point, or at a height of 19,470 feet, "and was the most elevated position at which any of us had ever lived. We remained there twenty-six consecutive hours, feeling slightly at first the effects of the low pressure, having the same symptoms as we noticed on Chimborazo; and we used chlorate of potash, and remarked its good effects. All the signs of mountain-sickness had passed away before we commenced the descent, and they did not recur again during the journey." The member of the party who suffered least from mountain-sickness was Mr. Perrin, the interpreter, who was in bad health from having led a dissipated life, and "could not walk a quarter of a mile on a flat road without desiring to sit down"; but he had lived for a long time at heights of between 9,000 and 10,000 feet, and had several times passed over a height of more than 14,000 feet; so that he was partly inured to the rarefied air. Chimborazo was visited again six months after the first visit, and a second measurement of the height was made. The mean of the two measurements gives 20,517 feet.

Structure of the Organs of Touch.—M. Ranvier has been much assisted in his investigation of the structure of the organs of touch by the examinations of the structure of infants. At birth, the nerves of touch may be found to pass into certain papillæ, on the palmar aspect of the fingers, immediately beneath the cells of the mucous layer of Malpighi, where they form a network of ramifications which, though distinct, are closely pressed together. No cellular elements are at this time mixed with the network, but a small collection of round cells exists beneath it. These gradually surround the network and pass in among its branches; the whole soon becomes united, and a tactile corpuscle is formed. Sometimes the corpuscle remains unilobar, but more frequently other lobes are formed in the same manner as the first one, and are joined to it. Hence it is that, in young children, the nerve-fibers which enter into the composition of the tactile corpuscles are separated by layers of cells, which, in the course of development, become pushed to the periphery of each lobe, and the most of them undergo a considerable atrophy. This fact suggests that they are not nervous in their nature, for the nerve-cells, so far from undergoing atrophy during growth, gradually increase in size to their full development. M. Ranvier has not perceived any communication between the nerve-fibers and the cells in the tactile corpuscle; the ramifying branches of the nerve-fibers, after a tortuous and usually complicated course, end in free, flattened knobs.

Influence of Physical Structure on Processes of Dyeing.—M. Gustave Engel has been engaged for several years in studying the influence which the physical structure of substances exercises upon the operations of dyeing, and has remarked that certain sands, composed of silica, a substance chemically inert, behave, in the presence of different coloring-matters and dyes, exactly in the same manner as cotton and wool. On examining with a microscope siliceous sands

having this property, they are found to be composed of the carapaces of tubular diatoms, formed of rings placed one upon the other. Each grain of the sand is, in fact, a minute tube of exceedingly fine silica, forming a mineral fiber which, by virtue of capillarity, retains coloring-matters with the same force as do vegetable or animal fibers dyed under the same conditions, and that without any chemical combination having taken place. M. Engel has exhibited to the Industrial Society of Mulhouse specimens of silica colored with alizarine rose, with indigo blue, and with a deep green produced by dyeing in logwood silica colored with iron, in all of which cases the siliceous sand had been treated as if it were cotton. Other specimens showed that the same sand behaved like wool in the presence of certain coloring-matters, especially of those derived from aniline. The experiments then make known a mineral substance which has properties of physical structure analogous to those of animal and vegetable fibers that are susceptible of being dyed, the likeness being given by the minute central canal, which enables each of the microscopic tubes to absorb the coloring-matter through capillary attraction, and to fix it so that it will resist chemical agents in the same manner as do organic fibers similarly colored. "These examples," says M. Engel, "tend to prove the new fact which I have been trying to establish, that the physical structure of substances submitted to the process of dyeing is of much more importance than their chemical composition, even if it is not the only factor in the process, as my experiments make it seem probable that it is."

M. Soleillet on the Sahara.—M. Soleillet lately made a communication to a society of civil engineers on his recent journey in the Sahara. This journey, the fourth which he has made since 1872, was undertaken chiefly for the purpose of finding what products of the soil could be made to contribute to the traffic of the proposed trans-Saharan railroad. He discovered coal in the Djebel Aroun, saltpeter in the region of Ain-Sala; in his journey to the Soodan, he found the butter-tree, which has been known since the days of Park, and sent specimens of the vegetable butter to M. Thénard. This product furnishes a stearine which melts at a high temperature, and can be made to give a clear white light, and has already been employed by the English in tempering certain steels, and in oiling steam-engines. In his last journey, he discovered a plant, the *Fernan*, a kind of *Fucus*, the white juice of which takes the place of pitch with the Moors; incorporated into the wood with a hot iron, it makes an excellent calking for boats. Hoping to find in it a substitute for India-rubber, he gave some of the juice to M. Thénard, who extracted from it a substance having properties similar to those of India-rubber, except that it was not elastic. It could be perfectly vulcanized, and in that state was much like gutta-percha. An oil was extracted from it, and a resin which could be converted by heat into a beautiful and brilliant lacquer. M. Soleillet was prevented by robbers from reaching Timbuctoo, but beyond Ain-Sala he discovered a large extent of country marked by dunes running north and south, which were crossed by others running from east to west. Between these dunes were ponds of both fresh and salt water, which left, when they were dried up, rich, natural meadows. The country, having an area equal to about a quarter of that of France, possesses a healthy climate, and is inhabited by ten thousand people. Farther on is the mountainous district of Adrar, inhabited by an agricultural and commercial Berber population, with whom the Portuguese carried on an important commerce in the fifteenth century.

The Human Fossil of Schipka Cave.—A human jawbone, found in the Schipka Cave of Moravia, along with bones of the mammoth and a number of rude stone implements, exhibits, according to a description given by Professor Schaffhausen, of Bonn, some remarkable and suggestive peculiarities. It is a fragment, consisting of a fore part of the lower jaw, containing the cutting-teeth, the eye-tooth, and the two premolars of the right side. The last three teeth are still undeveloped in the jaw, but have been brought into sight by the breaking away of a part of the bone. The remarkable feature of the bone is its size. The development of the teeth is that of a child in its eighth year, while it is cut-

ting its second teeth, but the proportions of the bone and of the teeth are those of a fully-grown person. The measurements of every part largely exceed those of similar parts in any child, and equal, in some points surpass, those of adults. Peculiarities were remarked in the shape of the fragment, as a retrocession of the lower part of the jaw, indicating the absence of a chin, and a very oblique slope of the hinder surface of the symphysis, as is observed in a higher degree in the anthropoids and in a lower degree in savage races and other fossils of men, such as the jaw of Nanette, with which this one has considerable similarity.

An Unpublished Letter of Sir Isaac Newton's.—At the *conversazione* given to Professor Helmholtz at University College, Mr. Latimer Clark exhibited the accompanying interesting unpublished letter from Sir Isaac Newton to Dr. Law:

"LONDON, *December* 15, 1716.

"DEAR DOCTOR: He that in ye mine of knowledge deepest diggeth, hath like every other miner ye least breathing time, and must sometimes at least come to terr; alt for air.

"In one of these respiratory intervals I now sit doune to write to you, my friend.

"You ask me how, with so much study, I manage to retene my health. Ah, my dear doctor, you have a better opinion of your lazy friend than he hath of himself. Morpheous is my best companion; without 8 or 9 hours of him yr correspondent is not worth one scavenger's peruke. My practizes did at ye first hurt my stomach, but now I eat heartily enow as y' will see when I come down beside you.

"I have been much amused by ye singular φενομενα resulting from bringing of a needle into contact with a piece of amber or resin fricated on silke clothe. Ye flame putteth me in mind of sheet lightning on a small—how very small—scale. But I shall in my epistles abjure Philosophy whereof when I come down to Sakly I'll give you enow. I began to scrawl at 5 mins frm 9 of ye clk, and have in writing consmd 10 mins. My Ld. Somerset is announced.

"Farewell, Gd bless you and help yr sincere friend (Signed) ISAAC NEWTON.

"To Dr. Law, Suffolk."

—*Nature.*

The Endowment of Research.—A meeting of the Fellows of the Royal Astronomical Society was lately held to consider the question of the endowment of research, when resolutions were offered by the Earl of Crawford, Sir Edmund Beckett, the Astronomer Royal, Captain Noble, and others, expressing opinions adverse to the granting of public money for scientific research where it does not appear that results useful to the public will be obtained, or where the researches proposed are likely to be undertaken by private individuals or public bodies, as not tending to the real advancement of science; disapproving the foundation of a physical observatory at the national expense; recommending the discontinuance of the Government grant to the Committee on Solar Physics; and calling for the publication of full accounts of all money expended by the Government for scientific purposes, and clear definitions of the nature of the work to be undertaken. The resolutions gave way to an amendment, which was adopted, declaring that no sufficient reason existed at present why the Society, in its corporate capacity, should express an opinion on the subject.

Frost-formed Earth-Beds.—Professor W. C. Kerr contributes to the "American Journal of Science" some observations on the superficial earths which cover the rocks of the Middle and South Atlantic States for a depth of from a few feet to twenty or thirty feet, and sometimes twice as much. The earths are easily discovered to be for the most part the result of the decomposition *in situ* of the exposed edges of the underlying strata, the vertical and highly inclined bedding lines of which are distinctly traceable by the eye through the earth-covering, and are seen to pass by insensible gradations into the undecayed rock beneath. The question is discussed, by what agency, and when, was this decomposition effected. The beds present, generally, unstratified masses of earth, interspersed with pebbles and coarser stones, with a general tendency of the heavier fragments to seek the bottom, or to descend, like a stream, to the lower levels of the formation. Indications of a proper stratification by the action of water are seldom present; and such action is excluded by the most obvious features of the deposits. The appearances point rather to a settling by some kind of movement of the mass. A clew to the origin of the beds is given by the mineral veins which rise to the level of their floors. Fragments of the mineral are thickly scattered around them,

and prove to be identical with the pebbles with which the earth is interspersed. The pebbles, then, originate from the veins, which have been broken up by the same agency that has caused the decomposition of the stratified rock. This agency Professor Kerr believes to have been the action of the frost of the glacial period, which, as we infer from observations made in northern latitudes, may readily have penetrated the rocks to the depth indicated by the character of the beds, and, constituting what might be called an earth-glacier, would have produced the same movements of the mass and of the particles among themselves as are seen to occur in the true glacier, differing only in amount. The deposits might then be called frost-drift, as distinguished from proper glacial drift. Instances of veins in course of actual disintegration are mentioned in the paper. In cutting a hill for the extension of Market Street in Philadelphia, in 1876, bands of hornblende and chlorite were found decomposed, drawn out, and bent over, as if in course of being carried down the slope, and a similar appearance is observable in a mica-mine in Yancey County, North Carolina. The gold-bearing gravels or placers of North Carolina belong to this class of frost-drifts, the gold and quartz pebbles being derived from the veins which have been broken down in the course of their formation.

Burying the Souls of the Drowned.—Whenever an Abchasian is drowned, his friends search carefully for the body; but, if this is not found, they proceed to capture the soul of the deceased, a measure which has then become a matter of importance. A goat-skin bag is sprinkled with water and placed with its mouth, which is stretched open over a hoop, looking toward the river, near to the place where the man is supposed to have been drowned. Two cords are stretched from the spot across the river, as a bridge on which the soul can come over. Vessels containing food and drink are set around the skin, and the friends of the deceased come and eat quietly, while a song is sung with instrumental accompaniments. The soul, it is believed, is attracted by the ceremonies, comes over on the bridge that is laid for it, and goes into the trap. As soon as it has entered—that is, when the bag is inflated by the breeze—the opening is quickly closed, and the bag is taken to the burial-place, where a grave has already been prepared. The bag is held with the opening to the grave, the strings are untied, and the soul—that is, the wind in the bag—is squeezed into the grave, and the burial is afterward completed. This rite is considered of equivalent value with the burial of the body, and the grave is treated with the same honor as if the body were really within it.

Alkaline Deposits from Waters of Irrigation.—Professor E. W. Hilgard, in his report as Professor of Agriculture in the University of California, observing that ordinary surface irrigation on alkaline lands tends to concentrate the alkali at the surface, proposes as a remedy underdraining, "which may so far lower the water-table from which the saline matters are derived, and may so far favor the washing out of the salts during the rainy season, that the latter will thereafter fail to reach the surface so as to accumulate to an injurious extent with reasonable tillage." The waters of Kern and Tulare Lakes contain an excess of solid matter, the quantity in the former lake being twenty-six times as much as in average river-water, and consisting mostly of carbonate of soda, common and Glauber's salts. The evaporation from such water when it is used in irrigation adds annually to the deposit of alkali in the soil, the effect of which must be counteracted by the cultivation of deep-rooted crops, the use of gypsum, sub-irrigation, and the leaching out of the alkali from time to time by long-continued flooding and underdrainage. Professor Hilgard concludes, after an examination of the facts, that "there are, probably, few river-waters in the world of such composition or natural purity that continued irrigation without correlative underdrainage can be practiced without in the end causing an injurious accumulation of soluble salts in the soil." The Indian Government, after having spent enormous sums to bring water upon the fields, now has to face the problem of its economical removal by drainage, so as to relieve the soil of the accumulated alkali which has rendered it unfit for cultivation.

The New Eddystone Lighthouse.—The last coping-stone of the new Eddystone Lighthouse was laid on the 1st of June by the Duke of Edinburgh. The foundation-stone was laid by the same prince as Master of the Trinity Board on August 19, 1879. It is expected that the tower will be ready for the exhibition of the light next March. The new tower is double the height of the old one, and is made of uniform granite. The light, instead of being fixed as at present, will be oscillating, and will consist of a powerful white, double-flashing half-minute light, showing two successive flashes of about two and a half seconds' duration, divided by an eclipse of about four seconds, the second flash being followed by an eclipse of about twenty-one seconds. The light will be visible all around the horizon, for seventeen and a half miles, and will overlap the light of the Lizard, where there are now eight miles of darkness. A subsidiary white light is to be mounted in an upper room, to cover the reef of rocks known as the Hand Deeps, which will be adjusted so as to be seen only within the area of danger occasioned by those rocks.

Sulphur Formation in the Soil of Paris.—M. Daubrée has called attention to a formation of native sulphur which is now going on in the soil of Paris. The mineral has been found in considerable quantities among the rubbish dug up from the Place de la République, presenting a crystalline appearance to the naked eye, and showing under the glass the octahedral forms which are most characteristic of the natural crystals. The origin of this substance, which is found in situations that preclude the supposition of emanations of illuminating gas having anything to do with it, is evidently to be ascribed to the presence of sulphate of lime, old plaster, and various organic matters which have been brought together during the last two centuries in the filling up of the ditch that formerly encircled the city. The sulphur occurs at a depth of from eight or ten inches to ten feet below the surface, and over an area of one hundred and sixty by fifty or sixty feet, forming in reality a kind of bed or deposit of the mineral. Specimens have been obtained from it of workable sulphur, analogous to that of Sicily and other countries, consisting of a breccia of small fragments incrusted with crystals of sulphur, cementing them one to another.

A Vegetable Digestive Agent.—M. Wurtz, in a paper read before the French Academy of Sciences, has drawn general attention to the great chemical and therapeutical value of *papaine*, a vegetable substance which excites the digestive faculty, as opium produces sleep. Both these substances are obtained in the same manner, by cutting into the epidermis of plants whose lactiferous vessels are charged with medical juices. The *Carica papaya*, or common papaw-tree, belongs to the family of the *Cucurbitaceæ*, or gourds; its straight, cylindrical trunk, from ten to sixteen feet high, is terminated at the top by a cluster of large palmate leaves, which give it the appearance of a palm-tree. The fruits, hanging in clusters under the leaves, have the shape of roundish cucumbers, and are much esteemed when ripe. The papaw appears to have originated in the Moluccas, but has been acclimated in India, Mauritius, the Island of Réunion, the Antilles, and a considerable part of South America. The milky juice which contains the papaine is white, slightly bitter, and styptic, free from tartness, has an acid reaction, and is so highly charged with albumen that Vauquelin compared it to blood deprived of its coloring-matter. It flows from incisions made in the bark and the green fruits, and is immediately bottled and sent to market either pure or with the addition of ten or twelve per cent. of alcohol to prevent fermentation. If pure, it comes coagulated; if mixed with alcohol, it remains liquid, and, after standing, separates into a clear liquid and a white precipitate, composed in great part of albumen, fibrine, and a considerable quantity of precipitated papaine. Alcohol precipitates from it crude papaine; this, after being washed in alcohol and ether, to remove fatty matters, is again dissolved in water. The precipitate from this solution is pure papaine, which, when purified by dyalise, has the composition of an albuminoid substance. Papaine, refined with the sub-acetate of lead, offers several distinctive characteristics, among which are: 1. It is very soluble in water, dissolving like a gum; 2. The solution makes a lather

with water; 3. The solution becomes turbid in boiling, without coagulating; when it is curdy it sometimes leaves an insoluble residue in water; left to stand, the solution becomes turbid after some days, and a microscopic examination shows it to be filled with vibriones; 4. In the presence of a saccharine liquid, papaine acts as an alcoholic ferment, with an extraordinary energy and promptitude, but the digestive property may be arrested by the application of benzoic or salicylic acid. The most important property of papaine, and one which puts it in the rank of the most powerful digestive ferments, is its action on meats. One part of papaine will digest and transform into soluble peptone from two hundred and fifty to three hundred parts of meat. Its solubility in different fluids allows it to be used in a great many pharmaceutical forms; and, being a vegetable juice, it can be preserved with more stability than animal ferments, and can be kept indefinitely when dry.

NOTES.

Mr. E. F. Horton gives an account, in the "Kansas City Review," of the opening of a mound thirty or forty feet in diameter, near Trenton, Missouri, June 9th, in which at least twenty-five human skeletons, but no relics or implements, were found. He estimates that the mound has contained from one hundred and fifty to two hundred skeletons, and says: "There appears to have been a stone floor on which the bodies have been placed; over them a stone covering, supported, probably, by stones set edgewise, upon which were other bodies; this continuing until there were four layers of corpses and five layers of stone."

Mr. Gerard Krefft, a naturalist distinguished for his work in the natural history of Australia, died in February last. He was born in Brunswick, Germany, in 1830, early conceived a taste for natural history, and went to Melbourne in 1852, after having spent some time in the United States. He went out in the collecting expedition which was dispatched by the Victorian Government in 1858, became its leader, and supplemented the collection of specimens which he brought back with a full report concerning the animals he obtained, and the manners and habits of the aborigines. Having spent a short time in Europe, he returned to Sydney, and became connected with the Australian Museum, and eventually its curator, till 1874.

The International Geological Congress, which held its first session in Paris, in 1878, will meet at Bologna, Italy, September 26th, under the honorary presidency of Signor Sella. The King of Italy has taken a warm interest in the meeting, and has made considerable efforts to assure its success. A geological exposition will be held during the sessions, and excursions will be made to various points of interest. The reports of the International Committee appointed in 1878, on the unification of geological nomenclature and the conventional signs (figures and colors) used for charts, will soon be mailed to subscribers to the Congress. This question has been made a subject for competitive essays, for which prizes given by King Humbert are to be distributed by a jury.

M. Fievez, of the Brussels Observatory, has produced a new argument against Mr. Lockyer's theory that the spectrum furnishes evidence that some of the terrestrial elements are resolved into simpler constituents by the solar heat. Mr. Lockyer's view is based on the fact that some of the spectral lines of elements are shortened, disappear, or are unequally reversed in solar observation. M. Fievez has found that he can cause two of the lines of hydrogen to disappear, without any change in temperature taking place, by simply reducing the intensity of the light, as when he diminishes the aperture of his instrument during the observation. The lines shorten and go out as the aperture is drawn up; appear and lengthen when it is opened again. Similar results were obtained with the spectra of nitrogen and magnesium; and the phenomena of reversal noticed by Mr. Lockyer were also produced by changing the intensity of the light.

Mr. C. Shaler Smith has applied the results of the observations of several years to the estimation of the amount of pressure that has been exercised by the wind in gusts of extraordinary violence. The most violent storm of which he has a record occurred at East St. Louis, Ill., in 1871, when a locomotive was blown over by a wind-pressure of 93 pounds per square foot. The jail at St. Charles, Mo., was destroyed in 1877, by a pressure of 84·3; a brick dwelling at Marshfield, Mo., in 1880, by a force of 58 pounds per square foot. Railway-trains may be blown from the track, and bridges prostrated by pressures of from 24 to 31 pounds per square foot. These estimates are based upon the calculation of the smallest amount of pressure that would do the damage.

The magnetic survey of Missouri is to be continued during the summer at the expense of a gentleman in St. Louis. The State Legislature has rejected a bill author-

izing the county courts to employ competent persons to fix the north and south lines at the county-seats, at an expense of not more than fifty dollars each.

RECENT experiments by Nies and Winkelman indicate that expansion, in passing from the liquid to the solid state, is a more common property of metals than has been believed. Their fundamental experiment consisted in putting the solid metal into the liquid. In some cases the difference in density could be measured. They found that six out of eight metals examined distinctly expanded in solidifying, while the result was obscure in the case of the other two metals. Tin increased in volume 0·7 per cent.; zinc, 0·2 per cent.; bismuth, 3 per cent.; and antimony, iron, and copper in obvious proportions. Lead and cadmium presented difficulties that hindered a satisfactory determination of their qualities.

KRAUT has shown that ordinary combustible substances may be set on fire by nitric acid. A wooden box of convenient size was half filled with sawdust, hay, straw, tow, or shavings. A flask containing nitric acid, of at least 1·5 specific gravity, was placed upon this, and the box filled up with the combustible material. The flask was then broken, and a wooden cover was put on the box. Vapors were seen in one or two minutes; a thick, white smoke appeared a little later; and the odor of the burning material was observed. On opening the box a few minutes afterward, the interior was found all on fire, and flames burst out.

M. E. VILLARI, from experimental measurements of the temperature of the body during acts of motion, has reached the conclusions that the lowest temperature in man, ensuing after a period of rest, is 98·4°; that the temperature increases, under the influence of a positive, ascending effort, to 100·6°, under the influence of a descending effort to 100·3°; that it increases after any exertion, but more after an ascending than after a descending one; and that the chemical actions of the organism are augmented after every movement.

A SUNDAY Science School at Edinburgh, Scotland, has enrolled ninety-two pupils, and enjoyed an average attendance, from November to July last, of sixty youth who were not able on account of late business hours to attend the evening classes.

M. PICTET recently read a paper before the French Society of Civil Engineers, explaining the operation of his ice-machines, at the close of which he invited the members of the society to visit his works, where two machines are operating with sulphurous acid, one of which produces 2,425 pounds of ice per hour.

THE first number of Volume II of "Studies from the Biological Laboratory of John Hopkins University" is just published, and contains among others a lengthy but very interesting article on "The Study of Human Anatomy historically and legally considered."

MR. RONALD CAMPBELL GUNN, a Tasmanian botanist, died March 14th, aged seventy-three years. He was born at the Cape of Good Hope, and, having removed to Tasmania in 1830, was intrusted with important official positions. He began to investigate the botany and natural history of the island in 1830, and in this occupation rambled over most of the colony. Reports of his work appear in Sir Joseph D. Hooker's "Flora of Tasmania," and in several periodical publications. He was also editor of the "Tasmanian Journal," a scientific publication.

ALMOST simultaneously with the publication of the discoveries of Messrs. Bell and Tainter in radiophony, M. Mercadier, in Paris, without any knowledge of what they had done, announced that he had been able to reproduce the sounds of speaking and singing upon the photophonic receiver, not only with the light of the sun, but also by means of the electric light, and the oxy-hydrogen light.

MR. JOHN BLACKWALL, one of the oldest members of the Linnæan Society, died May 11th, aged ninety-two years. His principal work was a monograph on the British spiders, published by the Ray Society, about twenty years ago. He also published "Researches in Zoölogy," in 1834 (second edition, 1873), and a considerable number of papers on general zoölogy.

A MARKET for the sale of toads to gardeners is held regularly every week in Paris. Dealers bring their "goods" in well-ventilated casks, in which the toads are packed in lots of a hundred, in damp moss. A lot of a hundred good individuals will bring fifteen to seventeen dollars. The gardeners use them to keep down the destructive insects that annoy them. A Dutch gardener, M. Krelage, of Haarlem, recommends the use of the toad in greenhouses, as furnishing an excellent means for destroying the millepeds that infest the plants.

AN International Medical and Sanitary Exhibition is to be held under the auspices of the Parkes Museum of Hygiene at South Kensington from July 16th to August 13th. It will comprise everything that is of service for the prevention, detection, cure, and alleviation of disease.

THE French Association for the Advancement of Science will meet at Rochelle next year.

JAMES CRAIG WATSON.